

**Toward 21st Century Wundermaschinen –
A Practice-based Inquiry Developing Media Archaeology as an
Artistic Methodology**

Ping-Yeh Li

Doctor of Philosophy

Culture Lab, School of Arts and Cultures

Newcastle University

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Abstract

This practice-based thesis aims to construct a practice framework in the field of new media art that can be multi-disciplinary, reflective and productive in nature, and has potential implications for the relationship of humans and machines in the 21st Century. The core focus of this research is on how a media archaeological exploration of Wundermaschinen promotes an approach to Media Art practice that engenders wonder and expands our vocabulary about wonder is.

Building on reflections on creative projects *Sensing Energies* (2012) and *Spirit Exposure* (2012-2013), specific concerns emerged. It is argued that further practices of information visualisation move away from scientific and explanatory means, and otherwise explore how they are in line with similar developments in Media Art practice. It is then recommended to embrace a paleontological view on media development, and explore the hidden motives in practice of technology for observation. In other words, a media archaeological approach is adapted to excavate the family resemblance characteristics and unrealized dreams of Wundermaschinen. A review of contemporary maker-culture also suggested that we go beyond the homogenisation of novelty in open source making and examine specific experimental aspects.

To inform making activities thus conceived, a speculative framework of '21st Century Wundermaschinen' is proposed: rarity and refined labour, information-oriented visual complexity, performance-like setting for specific sensuousness, embracing knowledge across disciplines, assembling multiple epochal technologies, and machinery of curiosity. This framework is then applied through five experimental projects conducted between 2013 and 2016 that each has been documented the developmental context, implementation, technical

details and audience response. The results of this application are discussed and reflected to locate their characteristics of experience, aesthetic potential, and suitability for media research.

This practice-based research makes the following contributions: (i) a design framework for new media practitioners and HCI designers, (ii) a method of utilizing maker tools that critically contextualise themselves to broader techno-historical context of technology, (iii) an aesthetic and analytic strategy expressed as a framework which re-examines contemporary human-machine relationships, and (iv) a set of provocative examples that reflects on, and provides practical examples for, a media archaeology as artistic methodology.

Keywords

Wundermaschine, Machine of Wonder, Media Archaeology, Information Visualisation, Maker-culture, New Media Art, Human Computer Interaction

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Exhibitions

Mar 2016, *Loops-Layers-Lines*, Culture Lab, Newcastle University, UK.

Nov 2014, *Botanical Universe*, Culture Lab, Newcastle University, UK.

Aug 2014, *#UNPITCH_Action_4 ///*, Culture Lab, Newcastle University, UK.

Jul 2014, *The Hypnopompic State*, Culture Lab, Newcastle University, UK.

Dec 2013, *Experiential Converter V.1*, Culture Lab, Newcastle University, UK.

July 2013, *Samsare Eye V.2*, Townsville, Queensland, Australia.

Dec 2012, *Sensing Energies*, Culture Lab, Newcastle University, UK.

Workshops

Mar 2016, *Toward 21st Century Wundermaschinen – A Practice-based Inquiry into Information Representation as Media Art Practice*, Taiwan Scientific Symposium in Edinburgh, Edinburgh University, U.K.

Dec 2014, *Interactivity, Informativity and Sensitivity – Introduction of contemporary code-based art work*, Da-Jhen University of Technology, Pingtung, Taiwan.

Mar 2014, *Advanced Coding with Processing—Serial communication & Object Oriented Programming*, Space 4/5, Culture Lab, Newcastle University, UK.

Mar 2014, *Interaction with Kinect— User body tracking and interaction*, Space 11, Culture Lab, Newcastle University, UK.

Nov 2013, *Body, Flow and Technology: New Experiences through Biofeedback Art*, Taiwan Scientific Symposium in Newcastle University, Newcastle, U.K.

Table of Contents

| | | |
|------------------|--|-----------|
| Chapter 1 | Background, Inquiries and Methodology..... | 1 |
| 1.1 | Background | 1 |
| 1.2 | Motivations..... | 5 |
| 1.2.1 | Experimenting with the Aesthetic Possibilities in Everyday Electronics..... | 5 |
| 1.2.2 | Re-considering the Human-machine Relationship | 7 |
| 1.3 | Research Questions | 9 |
| 1.4 | Aims and Objectives | 10 |
| 1.4.1 | Aims | 10 |
| 1.4.2 | Objectives | 10 |
| 1.5 | Methodology: A Practice-based and Pragmatist Approach..... | 11 |
| 1.5.1 | Contextual Review: Constructing a Practice Framework..... | 14 |
| 1.5.2 | Media Archaeology: Excavating the Unrealized Dreams | 15 |
| 1.5.3 | Interdisciplinary Approach to Making: Art, Design and Engineering | 17 |
| 1.5.4 | Reflective Prototyping | 18 |
| Chapter 2 | Information Visualisation and Wonder: Reflections through Early Projects | 21 |
| 2.1 | Introduction | 21 |
| 2.2 | Experimental Project: Sensing Energies (Sep – Dec 2012) | 21 |
| 2.2.1 | Methodology | 21 |
| 2.2.2 | Aims and Developmental Context..... | 22 |
| 2.2.3 | Design, Implementation and Aesthetics | 23 |
| 2.2.4 | Technical Description..... | 26 |
| 2.2.5 | Audience Response and Self-reflection..... | 26 |
| 2.2.6 | Implications: Inquiries into the Potential Link between Information Visualisation and Wonder | 28 |
| 2.2.7 | New Knowledge Occurred in the Making..... | 29 |
| 2.3 | Experimental Project: Spirit Exposure V.1 and V.2 (Nov 2012 – Jun 2013) | 29 |
| 2.3.1 | Methodology | 29 |
| 2.3.2 | Aims and Developmental Context..... | 30 |
| 2.3.3 | Design, Implementation and Aesthetics | 30 |
| 2.3.4 | Technical Description..... | 31 |
| 2.3.5 | Audience Response and Self-reflection..... | 34 |

| | | |
|------------|--|-----------|
| 2.3.6 | Implications: Media Practitioner as Engineer, Psychic and Magician | 36 |
| 2.3.7 | Implications: Techno-historical Relationship and Wonder | 39 |
| 2.3.8 | New Knowledge Occurred in the Making | 39 |
| 2.4 | Specific Concerns toward Machines of Wonder | 39 |

Chapter 3 Speculations: Canonical Wundermaschinen and Contemporary Machine Prototyping 43

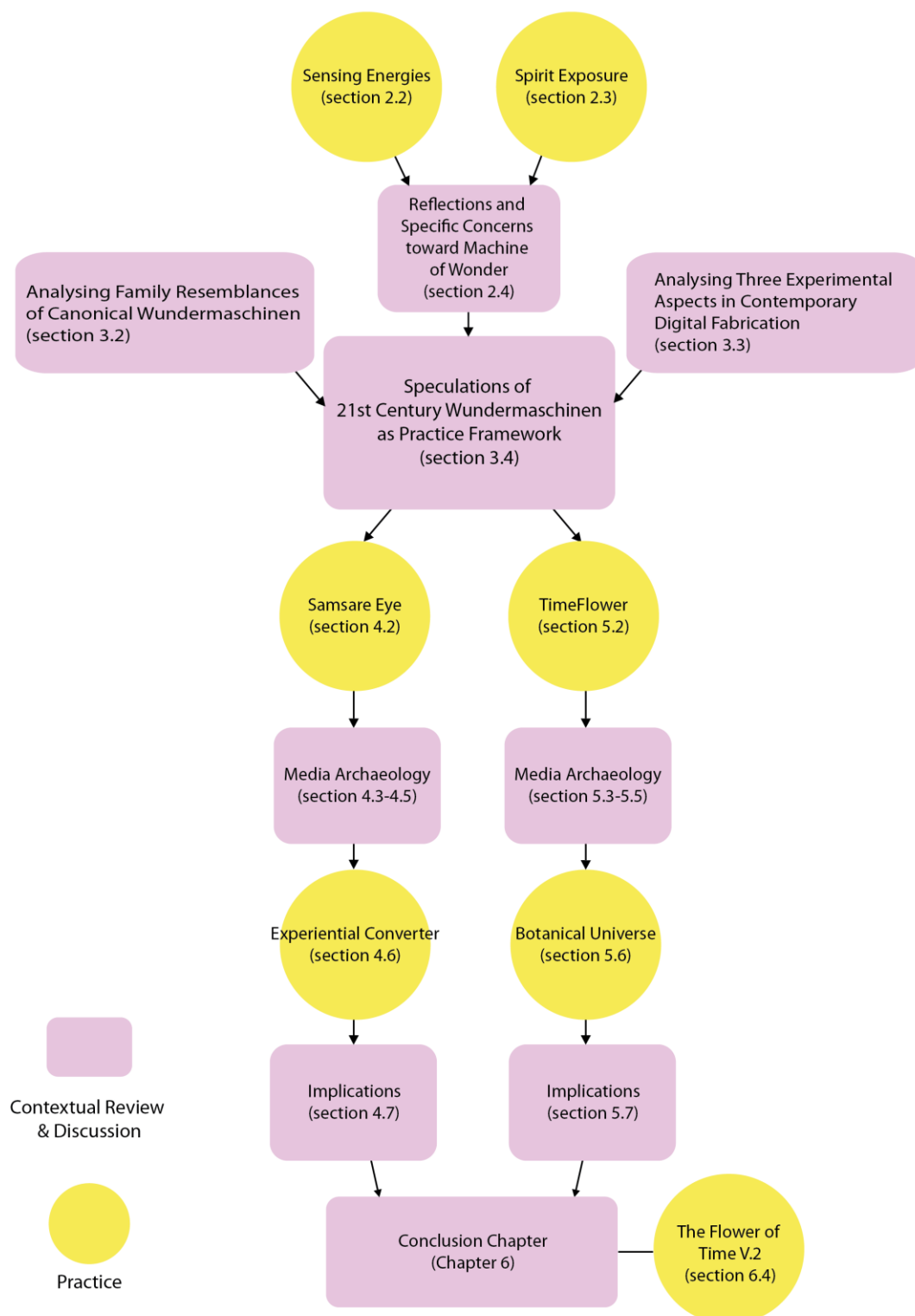
| | | |
|------------|--|-----------|
| 3.1 | Introduction | 43 |
| 3.2 | Wonder: A Brief Historical and Cultural Analysis | 43 |
| 3.2.1 | Wonder and the Birth of Philosophy | 44 |
| 3.2.2 | Wonder as a Wide Spectrum of Emotions | 45 |
| 3.2.3 | From the Observing Subject to the World Observed | 47 |
| 3.2.4 | Wonder and Aesthetics of the Sublime | 47 |
| 3.2.5 | Technological Sublime | 49 |
| 3.2.6 | Concept of Wonder: A Complex and Shifting Idea | 50 |
| 3.3 | A Review of Canonical Wundermaschinen | 51 |
| 3.3.1 | Automata as Models of Cosmology, Physiology and Society – A Media Archaeological Perspective | 51 |
| 3.3.2 | Metaphorical Artefacts: Clockwork Automata | 53 |
| 3.3.3 | Mimetic Motions: Performance Dolls | 59 |
| 3.3.4 | Mechanisms of Illusion and Trickery: Magical Machines | 67 |
| 3.4 | Creative Machine Prototyping in the Emerging Maker-culture | 72 |
| 3.4.1 | Computer-assisted Fabrication: Accurate, Individualized and Nomadic | 72 |
| 3.4.2 | Reflections through Open Source Making: Homogenisation of Novelty | 76 |
| 3.4.3 | Proposing Three Experimental Aspects in Digital Fabrication | 79 |
| 3.5 | From Critical Analysis of Canonical Wundermaschinen to Speculations of Contemporary Wundermaschinen | 82 |
| 3.5.1 | Rarity and Refined Labour | 84 |
| 3.5.2 | Information-oriented Visual Complexity | 84 |
| 3.5.3 | Performance-like Setting for Specific Sensuousness | 84 |
| 3.5.4 | Embracing Knowledge across Disciplines | 85 |
| 3.5.5 | Assembling Multiple Epochal Technologies | 85 |
| 3.5.6 | Machinery of Curiosity through Occurrent Processing | 86 |
| 3.5.7 | Object of Philosophical Argument | 86 |
| 3.6 | Summary | 87 |

| | | |
|------------------|--|------------|
| Chapter 4 | Developing Wundermaschinen of Correspondence | 89 |
| 4.1 | Introduction | 89 |
| 4.2 | Experimental Project– Samsare Eye (Dec 2012 – Jun 2013) | 90 |
| 4.2.1 | Methodology | 90 |
| 4.2.2 | Aims and Developmental Context..... | 90 |
| 4.2.3 | Design, Implementation and Aesthetics | 91 |
| 4.2.4 | Technical Description..... | 95 |
| 4.2.5 | Audience Response and Self-reflection..... | 100 |
| 4.2.6 | Implications: Toward a Media Archaeology of Correspondence Media..... | 103 |
| 4.2.7 | New Knowledge Occurred in the Making..... | 104 |
| 4.3 | From Correspondence Media to Unrealized Dreams | 105 |
| 4.3.1 | Correspondence Media for Disclosure of Regularities in Nature: Mundane Monochord..... | 105 |
| 4.3.2 | Correspondence Media for the Pursuit of Harmony: Bishop’s Colour Organ | 110 |
| 4.3.3 | Correspondence Media for Communication with the Incommunicable: Eyeborg | 115 |
| 4.4 | Three Unrealized Dreams of Correspondence Media | 118 |
| 4.4.1 | Dual Instrument for Co-occurrent Phenomena..... | 118 |
| 4.4.2 | Subtle Light Organ for Spiritual Resonance | 119 |
| 4.4.3 | Apparatus for Communicating a Cross-modal Language in a Cross-cultural Setting | 120 |
| 4.5 | Toward Wundermaschine of Correspondence..... | 121 |
| 4.6 | Experimental Project – Experiential Converter V.1 & V.2 (Oct 2013 – Jul 2014) | 121 |
| 4.6.1 | Methodology | 121 |
| 4.6.2 | Aims and Developmental Context..... | 122 |
| 4.6.3 | Design, Implementation and Aesthetics | 122 |
| 4.6.4 | General Technical Description | 127 |
| 4.6.5 | Technical Description: Dual Instrument for Co-occurrent Phenomena..... | 136 |
| 4.6.6 | Technical Description: Subtle Light Organ for Spiritual Resonance..... | 136 |
| 4.6.7 | Technical Description: Apparatus for Communicating a Cross-modal Language in a Cross-cultural Setting..... | 137 |
| 4.6.8 | Audience Response and Self-reflection..... | 138 |
| 4.6.9 | Implications: Dual Instrument of Live Information Transformation | 139 |
| 4.6.10 | Implications: Media Archaeology as Artistic Methodology | 142 |
| 4.6.11 | New Knowledge Occurred in the Making..... | 143 |

| | | |
|------------------|---|------------|
| 4.7 | Future Developments..... | 144 |
| Chapter 5 | Developing Wundermaschinen of Revelation..... | 147 |
| 5.1 | Introduction | 147 |
| 5.2 | Experimental Project – TimeFlower (Feb – Aug 2013)..... | 148 |
| 5.2.1 | Methodology..... | 148 |
| 5.2.2 | Aims and Developmental Context | 148 |
| 5.2.3 | Design, Implementation and Aesthetics..... | 149 |
| 5.2.4 | Technical Description..... | 149 |
| 5.2.5 | Audience Response and Self-reflection..... | 157 |
| 5.2.6 | Implications: Toward a Media Archaeology of Clock Mechanism..... | 158 |
| 5.2.7 | New Knowledge Occurred in the Making..... | 159 |
| 5.3 | From Historical Clock Metaphors to Unrealized Dreams | 159 |
| 5.3.1 | Mechanism of Divinity: Strasbourg Astronomical Clock and Natural Theology..... | 159 |
| 5.3.2 | Mechanism of Divinity: Wang Zi Won’s Mechanical Avalokiteśvara..... | 164 |
| 5.3.3 | Mechanisms of Social Dream: The Later Middle Age Clock as Civil Philosophy..... | 167 |
| 5.3.4 | Mechanism of Social Dream: Gilberto Esparza’s Plantas Nómadas..... | 171 |
| 5.4 | Two Unrealized Dreams of Clock Mechanism | 174 |
| 5.4.1 | Responsive Movements of Serenity, Wisdom and Peace..... | 174 |
| 5.4.2 | Nature as Authority in Clock Mechanism | 175 |
| 5.5 | Toward Wundermaschine of Revelation | 175 |
| 5.6 | Experimental Project – Botanical Universe (Apr –Dec 2014) | 176 |
| 5.6.1 | Methodology..... | 176 |
| 5.6.2 | Aims and Developmental Context | 176 |
| 5.6.3 | Design, Implementation and Aesthetics..... | 177 |
| 5.6.4 | General Technical Description..... | 181 |
| 5.6.5 | Technical Description: Responsive Movements of Serenity, Wisdom and Peace..... | 186 |
| 5.6.6 | Technical Description: Nature as Authority in Clock Mechanism..... | 187 |
| 5.6.7 | Audience Response and Self-reflection..... | 188 |
| 5.6.8 | Implications: Divergent Materialities of Wundermaschinen | 190 |
| 5.6.9 | New Knowledge Occurred in the Making..... | 192 |
| 5.7 | Future Developments..... | 193 |
| Chapter 6 | The Dawn of the 21st Century Wundermaschinen..... | 195 |
| 6.1 | Resume of Work Done | 195 |

| | | |
|--|--|------------|
| 6.2 | Re-engagement with Research Questions..... | 197 |
| 6.2.1 | How can we approach the machine of wonder as a framework for creative media design? | 197 |
| 6.2.2 | How can we prototype a 21 st century machine of wonder and what are the characteristics of experience, potential of aesthetics, and media research tendencies involved in so doing? | 197 |
| 6.3 | Selected Implications..... | 201 |
| 6.3.1 | Revisiting Initial Literature Review and Discussions | 202 |
| 6.3.2 | Lessons for HCI Researchers..... | 203 |
| 6.3.3 | Lessons for Media Archaeology | 205 |
| 6.3.4 | Lessons for Maker-Culture..... | 207 |
| 6.3.5 | Lessons for Philosophical Thinking about Human-machine Relationship | 209 |
| 6.3.6 | Lessons for Spiritual Practices | 211 |
| 6.4 | Finalising Project: The Flower of Time V.2 (Jan – Mar 2016)..... | 213 |
| 6.4.1 | Methodology | 213 |
| 6.4.2 | Aims and Developmental Context..... | 213 |
| 6.4.3 | Design, Implementation and Aesthetics | 216 |
| 6.4.4 | Technical Description..... | 216 |
| 6.4.5 | Audience Response and Self-reflection..... | 220 |
| 6.4.6 | New Knowledge Occurred in the Making..... | 220 |
| 6.5 | Limitations of the Evaluation Methods of this Research..... | 222 |
| 6.6 | Future Work..... | 223 |
| 6.6.1 | New Media as Dual Instrument..... | 223 |
| 6.6.2 | 21st Century Wundermaschinen as Art Practice..... | 224 |
| Appendices I: Video Documentations of Artworks | | 227 |
| Appendices II: Developmental Process of Artworks..... | | 229 |
| Bibliography..... | | 319 |

Alternative Contents List



List of Figures

| | |
|---|----|
| Figure 1 <i>Behind the City</i> (2003). Oil painting using computer image-montaging techniques (in <i>Photoshop</i>) | 2 |
| Figure 2 <i>Model PLGF2-3</i> (2009). Pseudo-scientific botanical drawings and model. | 3 |
| Figure 3 <i>Fog Forest</i> (2012). A 3D environment design..... | 3 |
| Figure 4 Website published for ‘reflective prototyping’ at: http://www.pingyehli.com/ | 19 |
| Figure 5 <i>W.I.P</i> show in Culture Lab, Newcastle University, UK, Dec 2012 | 23 |
| Figure 6 Visualisation of <i>Sensing Energies</i> (2012)..... | 24 |
| Figure 7 Demonstration of <i>Sensing Energies</i> in <i>W.I.P.</i> show, Dec 2012..... | 27 |
| Figure 8 <i>Spirit Exposure V.1</i> image captured in Northumberland Street, Newcastle, UK, 2012 | 32 |
| Figure 9 <i>Spirit Exposure V.1</i> image captured in Northumberland Street, Newcastle, UK, 2012 | 34 |
| Figure 10 <i>Spirit Exposure V.1</i> image captured in Central Station, Newcastle, UK. | 35 |
| Figure 11 <i>Spirit Exposure V.2</i> animation still image, originally captured in Northumberland Street, Newcastle, UK, 2013 | 35 |
| Figure 12 Martin Howse (2015) <i>A Return to the Earth</i> | 37 |
| Figure 13 Francis Bacon (1979-1980) <i>Three Studies for a Self-Portrait</i> , lithograph printed in colours on Arches paper, 47 x 103.5 cm..... | 38 |
| Figure 14 A later version of <i>Spirit Exposure</i> that renders one minute of a video “ <i>Francis Bacon: Fragments of a Portrait</i> ”, a TV documentary interview of Bacon by David Sylvester, broadcast on BBC1, 18 September 1966..... | 38 |
| Figure 15 <i>Carillon Clock with Automata</i> (1589), by Isaac Habrecht, The British Museum | 55 |

| | |
|--|-----|
| Figure 16 Isaac de Caus’s <i>Threatening Owl and Intimidated Birds</i> Automata. Image from The New York Public Library Digital Collections | 61 |
| Figure 17 The simulative hand of the <i>Harpsichord Player</i> (called <i>Lamusicienne</i>) made by Pierre and Henri- Louis Jaquet-Droz, La Chaux-de-Fonds, 1772–1774 | 63 |
| Figure 18 <i>All-Writing Miraculous Machine</i> (Allesschreibende Wundermaschine) by Friedrich von Knaus in 1760..... | 65 |
| Figure 19 An engraving of <i>The Turk</i> from Karl Gottlieb von Windisch’s 1784 book <i>Inanimate Reason</i> | 69 |
| Figure 20 John Keely and his “hydro-pneumatic-pulsating-vacu-engine” in 1895. 70 | |
| Figure 21 <i>The Bacon Alarm Clock</i> by Llopez, 2005. Image from: <i>Instructables</i> | 74 |
| Figure 22 <i>Arduino Vocal Effects Box</i> at <i>Instructables</i> | 79 |
| Figure 23 <i>Samsare Eye</i> and viewer interaction..... | 91 |
| Figure 24 An abstracted visual effect designed and rendered using Maya in the experimentations during the development of <i>Samsare Eye</i> | 92 |
| Figure 25 The 14th century Tibetan <i>Mandala</i> of Vajravarahi | 93 |
| Figure 26 <i>Thangka</i> of the Buddhist Deities Chakrasamvara and Vajravarahi. Mineral pigments and traces of gold on cotton cloth, around 15th century..... | 94 |
| Figure 27 A screenshot showing the 3D Model design in <i>Maya</i> (left) and its preview in <i>Processing</i> (right)..... | 95 |
| Figure 28 The algorithm in <i>Processing</i> that averages the changing position data .. | 97 |
| Figure 29 The Visualisation of <i>Samsare Eye</i> | 98 |
| Figure 30 The colour and shape of the eye is responsive to the viewer’s posture (see main text for explanation) | 101 |
| Figure 31 Fludd’s <i>Mundane Monochord</i> . Image from (Fludd, 1617, p.90) | 108 |

| | |
|---|-----|
| Figure 32 Model and exterior of Bainbridge Bishop's Colour Organ. Image from: Bainbridge Bishop, "A Souvenir of The Colour Organ" (1893)..... | 112 |
| Figure 33 Neil Harbisson and his <i>Eyeborg</i> , a device that can transpose colour frequencies into sound frequencies..... | 116 |
| Figure 34 The performance of <i>Experiential Converter V.2</i> | 123 |
| Figure 35 The exhibition setting of <i>Experiential Converter</i> in <i>W.I.P. Show</i> in Culture Lab, Dec 2013..... | 124 |
| Figure 36 The visual design of <i>Experiential Converter V.1</i> adopted a style of Jianzhi | 126 |
| Figure 37 The visual design of <i>Experiential Converter V.1</i> . The Chinese character is 'Yin', meaning 'sound' | 126 |
| Figure 38 The <i>Processing</i> codes for the compositional process: calculating an image's colour information and mapping it into a colour wheel..... | 128 |
| Figure 39 The mapping of <i>Starry Night</i> and <i>Lotus</i> into colour wheels | 129 |
| Figure 40 The <i>Colour Collector</i> | 130 |
| Figure 41 <i>PureData</i> patch and the visualisation of the performing colours | 131 |
| Figure 42 The <i>Motion Converter</i> was designed to convert colour into a kinetic colour-light experience | 132 |
| Figure 43 Correspondence between the colour wheel and dynamic light performance of an Ukiyoe woodprint. The left image as taken using long exposure photography | 133 |
| Figure 44 The performed colours were drawn into a colour pattern on site and saved as a file that could later be revisited (see main text for explanation) | 134 |
| Figure 45 The <i>Colour Collector</i> in <i>Experiential Converter V.2</i> | 135 |
| Figure 46 The performance collaborated with Taiwanese assistant professor/musician Jennie Lin | 136 |

| | |
|--|-----|
| Figure 47 Visualisation of <i>TimeFlower</i> | 150 |
| Figure 48 The representation of 10:07:12..... | 153 |
| Figure 49 The representation of 10:09:52..... | 153 |
| Figure 50 The un-blurred (left) and blurred effects (right)..... | 155 |
| Figure 51 Screenshot of <i>Processing</i> codes for creating blur effect in <i>TimeFlower</i> | 156 |
| Figure 52 <i>Strasbourg Astronomical Clock</i> . Woodcut by Tobias Stimmer (1574). | 161 |
| Figure 53 <i>Mechanical Avalokiteśvara</i> (2011) by Wang Zi Won..... | 166 |
| Figure 54 <i>Portrait of Mariana of Austria</i> . Diego Velázquez. Madrid, c. 1653. Vienna, Kunsthistorisches Museum..... | 169 |
| Figure 55 <i>Portrait of Armand Jean du Plessis de Richelieu</i> . Philippe de Champaigne, c. 1636. France, Condé Museum | 170 |
| Figure 56 <i>Plantas Nomadas</i> by Gilberto Esparza (2011) | 172 |
| Figure 57 <i>Plantas Nomadas</i> processing contaminated water | 174 |
| Figure 58 Exhibition setting of <i>Botanical Universe</i> in Space 5, Culture Lab, Nov 2014..... | 178 |
| Figure 59 <i>Botanical Clock</i> operating in an outdoor setting, Newcastle University, Nov 2014..... | 180 |
| Figure 60 Detail of <i>Botanical Clock</i> | 180 |
| Figure 61 Design schematics of the ticking mechanism (left) and the whole structure (right) of <i>Botanical Clock</i> | 181 |
| Figure 62 An ivy plant was installed in the centre of <i>Botanical Clock</i> with four environmental sensors..... | 183 |
| Figure 63 A meter showing the soil humidity (top) and light quantity (bottom) on <i>Botanical Clock</i> . For the light quantity meter, the shape of sun indicated bright environment while the shape of moon indicated dark environment | 183 |

| | |
|---|-----|
| Figure 64 In dark environment, the light quantity meter on <i>Botanical Clock</i> turned to the ‘moon position’ | 184 |
| Figure 65 Designing schematics for the two circular mechanisms in <i>Illustrator</i> ... | 185 |
| Figure 66 One of the <i>Circular Mechanisms</i> (a view from behind). They were constructed with MDF, <i>Arduino</i> board and stepper motors | 185 |
| Figure 67 Two small amplifiers were set behind the <i>Botanical Clock</i> | 186 |
| Figure 68 The exhibition setting of <i>Botanical Universe</i> in Culture Lab, Nov 2014, which included a video documentation of <i>Botanical Clock</i> installed in various environmental situations..... | 187 |
| Figure 69 <i>Botanical Universe</i> on show in Culture Lab, Nov 2014 | 191 |
| Figure 70 Thesis outline | 196 |
| Figure 71 Summary picture: showing the annotations in relationship to the artefacts produced | 200 |
| Figure 72 <i>The Flower of Time V.2</i> in Exhibition <i>Loops-Layers-Lines</i> | 214 |
| Figure 73 Designing of the mechanism of <i>The Flower of Time V.2</i> in <i>Illustrator</i> .217 | |
| Figure 74 The mechanical design of <i>The Flower of Time V.2</i> was an assemblage of four mechanical layers. The first layer on the left was the layer of second, then from left to right, the layer of minute, hour and day | 218 |
| Figure 75 The colour mapping scheme of <i>The Flower of Time V.2</i> | 219 |
| Figure 76 <i>The Flower of Time V.2</i> in Exhibition <i>Loops-Layers-Lines</i> | 221 |
| Figure 77 <i>The Flower of Time V.2</i> was assembled with transparent acrylic sheets. A colour light projection from the side of mechanism created accurate colour hues for each layer | 221 |
| Figure 78 <i>The Flower of Time V.2</i> in performance mode (see main text for explanation) | 222 |

Chapter 1 Background, Inquiries and Methodology

1.1 Background

This research has resulted from my continuous interest in juxtaposing diverse media and methods into art making, such as combining the computational and the painted, or the historical and the speculative. Between 1998 and 2003, I trained as a painter using charcoal, watercolour and Chinese ink. These multiple techniques were further developed during my four years of study at National Taiwan Normal University 2000-2004. My work was more about juxtaposing various materials and speculating potential issues than developing a specific artistic skill or identity. For example, I worked with printmaking onto objects or computer image montaging as a composition technique for oil paintings (Figure 1). In 2007, I joined the MFA course in Edinburgh College of Art, where I developed the *New Plant Species Found*¹ project. Influenced by the rich collections in the Edinburgh Royal Botanic Garden, this project was a series of pseudo-scientific botanical drawings and models displayed in a museum-like setting (Figure 2). Imaginary plants were made and illustrated by means of similar techniques to those used in scientific dissections and illustrations. Through the exhibition, I explored how the scientific and the imaginary means of visualization could be juxtaposed as an art installation. This series was exhibited in various venues in Edinburgh and Oxford, U.K. and in Kaohsiung, Taiwan. In 2010, I started working on three-dimensional (3D) environment design and programming projects (Figure 3) with colleagues in Taiwan. This experience inspired me to take up further study in the field of computational and interactive media.

¹ Project and exhibition documentation at: <http://www.pingyehli.com/DM/2009/10/21/new-species-found/>

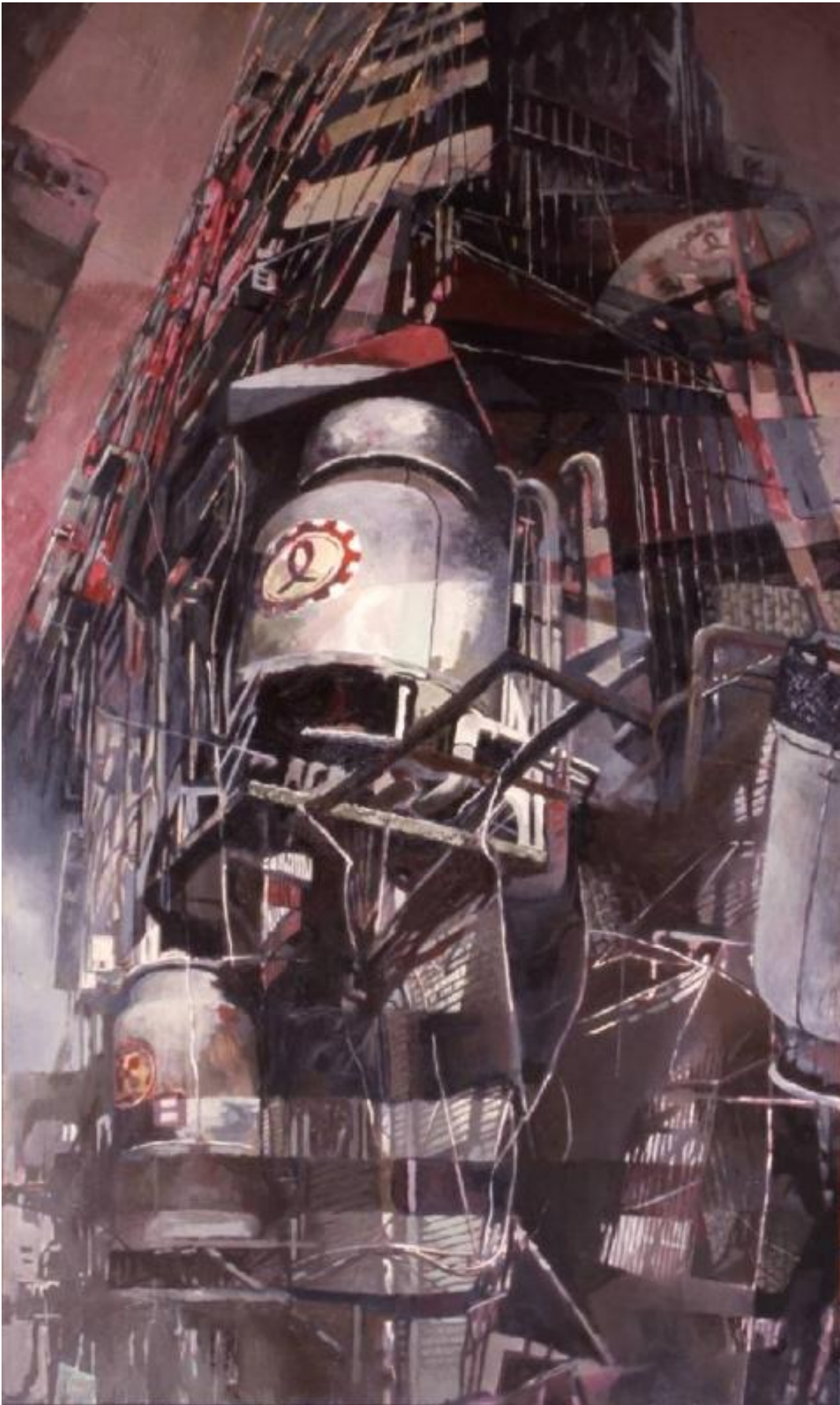


Figure 1 *Behind the City* (2003). Oil painting using computer image-montaging techniques (in *Photoshop*)

Computational technology not only influences how artists inquire, experiment and express through making, but also forms new challenges for creative practitioners. Since the 1950s we



Figure 2 *Model PLGF2-3* (2009). Pseudo-scientific botanical drawings and model



Figure 3 *Fog Forest* (2012). A 3D environment design

have witnessed the rise of various forms of art driven by computers: Interactive art, Software art, Net art, Game art etc. (Tribe, Jana & Grosenick, 2006, pp.6–25). These new media have already stimulated a general mixture of identities between artist, stage-magician and engineer. While the three identities have fundamental differences, how can their heterogeneous ways of research be fused and contribute to the world of knowledge? How can an individual produce novel artefacts adopting this hybrid identity? Considering that this role of artist-magician-engineer may continue to develop in the future, this research was conducted to provide practical and critical investigation for practitioners that share similar inquiries. As art and design research, it was inspired by the hybridism and multi-disciplinary nature widely seen in computational arts, and the ambiguous identity between artist, stage-magician and engineer shared by many in the present.

Media thinker Siegfried Zielinski examined the machines and media experiments that related to magic, alchemy, illusion and metaphors in fifteenth to nineteenth century Europe, and suggests that “formalizability and computation” and “intuition and imagination” constitute the heterogeneity of media practices (Zielinski, 2006, p.277). For Zielinski, the alchemists’ laboratories in pre-modern Europe demonstrated how the myth, curiosity, divine and science were interwoven. In these places the work of mixing and separation, dissecting and combining was viewed as work that was valuable and worthy of support. He argues that in the contemporary laboratories of experimental research into media worlds, there also lies the hope that the contemporary sorcerer’s apprentices, engineers, programmers and artists will succeed in “turning the digital into gold” (Zielinski, 2006, p.278). Such a notion of esotericism in new media practices can be seen in, for example, Martin Howse’s work (Nadja, 2013). Martin Howse’s practices often involve rendering computers into their composite elemental materials, extracting precious metals and re-crystallizing through mechanical and chemical processes. His improvised artefacts or performances typically involve transmitting or receiving hidden

information and energy through use of circuits and chemical reactions intermingling on tabletops (Hall, 2015). His ‘electro-alchemical hybrids’, ‘speculative hardware’ (Hall, 2015) and ‘digital dowsing’ (Nadja, 2013) engage the participants in meditation, reflection and revelation. These new media practices make the relationship between esotericism and technological artefacts an intriguing focus of contemporary media research, rather than something far away.

Accordingly, as a media practitioner/researcher concerned with this emerging identity of artist-magician-engineer, I conducted this practice-based research towards a concept of ‘machines of wonder’ (which will be explored in Chapter 3).

1.2 Motivations

1.2.1 *Experimenting with the Aesthetic Possibilities in Everyday Electronics*

Concerning the artist-magician-engineer identity, this research particularly embodies an attempt to produce with emerging tools machineries that are divergent from the qualities of the utilitarian machines of our everyday living. It explores how such an identity could creatively influence the formation and demonstration of technological objects, and how ‘aesthetic’ this could be. This interest in experimenting with the divergent qualities of the everyday coheres with a contemporaneous current in the art world:

“It results from the great increase in the number of artists worldwide and the opportunities offered by new informational and communicative technologies to millions of users. These changes have led to the viral spread of small-scale, interactive, DIY art that is concerned less with high art style or confrontational politics and more with tentative explorations of temporality, place, affiliation, and affect.” (Smith, 2009, p.188)

The emergence of creative computer-assisted DIY art draws on the vast reservoir of normally unnoticed, trivial and repetitive electronic artefacts and actions comprising the common ground of daily life. It examines impetus in the realms of the popular and the non-specialized for aesthetic potential. As Stephen Johnston makes clear in the introduction to his volume on *The Everyday* (Stephen, 2008), the rise of the everyday in creative arts is generally understood in terms of a desire to discuss:

“... how the aesthetic focus on everyday life brings fundamental but overlooked aspects of lived experience into visibility, while at the same time arguing for the socio-political importance of this visibility.” (Stephen, 2008, p.12)

In contrast to big budget art productions, this trend relies on the humblest materials and the re-arrangement of basic constituents to realize an intention: to turn to the everyday and bring art and life closer together. Abandoned materials, waste and obsolescent consumer goods are often used by art practitioners as a reaction against art’s perceived existence in “an autonomous and rarefied sphere of production and consumption” (Stephen, 2008, p.15), and to further understand what we need, and who we are. As French novelist Georges Perec (1997) contended earlier:

“What speaks to us, seemingly, is always the big event, the untoward, the extra-ordinary: the front-page splash, the banner headlines... How should we take account of, question, describe what happens every day and recurs everyday: the banal, the quotidian, the obvious, the common, the ordinary, the infra-ordinary, the background noise, the habitual?” (Perec, 1997, p.177)

In the spirit of Perec’s call for a new discovery of the ordinary, and the related concept of everydayness in art, my research investigates computational culture that could bring new potential in creative practice. It aims to know how the common qualities of ubiquitous

electronics (mass produced, planned-obsolescent, and low-cost) can become wondrous and extraordinary. This research advocates the novel usage of mundane electronic components to create machines of ‘rare and refined labour’ (which will be discussed in section 3.5.1), and utilizes low cost fabrications to assemble ‘epochal technology’ (which will be discussed in section 3.5.5). It also intends to find value in individual fabrication that provides alternatives to dominating consumerist ideologies, which are functional, fast-responsive and market-driven. Personal beliefs and reflections, instead of popular utilitarian thoughts and commonly understood techno-historical narratives, will be considered more critical in shaping practice.

1.2.2 *Re-considering the Human-machine Relationship*

Current discussions on human-machine configurations in Human Computer Interaction (HCI) research provide another motivation for this study. As a field focusing particularly on the interfaces between people (users) and computers, HCI observes the ways in which users interact with computers and develops computing applications that better respond to the needs of users. One of the contemporary issues in HCI aims to reframe the human-machine relationship from categorical debates to empirical investigations of concrete practices. Researchers who address such a notion suggest that human action is constantly constructed and reconstructed from dynamic interactions with the material and social worlds. As Lucy Suchman (2007) suggests:

“Human-machine configurations matter not only for their central place in contemporary imaginaries but also because cultural conceptions have material effects. As our relations with machines elaborate and intensify, questions of the humanlike capacities of machines, and machinelike attributes of humans, arise again and again. ” (L.Suchman, 2007, p.1)

Suchman challenges common assumptions behind the design of interactive systems. She suggests that the human-machine interface should not be taken as an a priori or self-evident boundary between bodies and machines. We should, instead, “recognize the deeply mutual constitution of humans and artefacts, and the enacted nature of the boundaries between them” (A. Suchman, 2007, p.263). A similar orientation of ‘Third Wave HCI’ that is characterised by lived-experience, intimacy and embodiment also coheres Suchman’s notion (Bowers, 2012, p.68). Adopting these ideas, my research is guided by the motivation to seek an experience of ‘wonder’ in human-computer interaction. By wonder, this research indicates the artefacts’ power to trigger the spectator’s imagination, questions, or further action through their experience. Wonder relates to the potential of artefacts to create a rare experience and awe in the spectator that is beyond calculation or measurement.

To show this more clearly, this idea of wonder can be illustrated by the collections in museums of technology. A nineteenth century European mechanical bird automaton and a Japanese mimetic Karakuri puppet were both artefacts designed for wonder. Their sophisticated mechanisms and refined craftsmanship not only showed clear intention to fascinate the viewers and encouraged detailed inspection, but also conveyed the long story of the interweaving between imagination, aesthetics and technology. The making of machines of these types required highly professional design and engineering with no less subtle skill of demonstration. More interestingly, a closer investigation will find them often discussed as the embodiment of the religious faith, cosmological worldview, or the ideals of the authoritarian state of the period in which they were created (which will be discussed in section 3.3). This commonly neglected human-machine relationship of wonder motivated this study to investigate the potential to make the everyday electronics of the 21st century mysterious and miraculous.

Therefore, as research toward machines of wonder, this thesis sets itself the task of investigating the fundamental issue of what constitutes wonder in new media and what part technological elements may play, through alternative methods of prototyping and demonstrating. This thesis will go beyond the simple fact of physical matter to encompass the work's existence more broadly: the production, physicality, function and all aspects that can be sensed and verified by the user/audience.

1.3 Research Questions

Driven by the background and motivations discussed above, this research was guided by two interlinking questions:

- **How can we approach the machine of wonder as a framework for creative media design?**

This initial research question will be explored throughout the contextual review of canonical Wundermaschinen (in section 3.3) and contemporary maker-culture (in section 3.4), and will be responded to in section 3.5, where 'machine of wonder' will be described as a framework of design for the seven projects conducted in this study.

- **How can we prototype a 21st century machine of wonder and what are the characteristics of experience, potential of aesthetics, and media research tendencies involved in so doing?**

The second question emerged at a later stage of research. It was acknowledged through contextual review that the historical machines of wonder should be observed and analyzed in correspondence with their social, religious or political background (which will be discussed in

section 3.3). The critical value of these machines was regarded as a reflection of socio-cultural and religious concerns of specific eras, rather than simply a process of technological progress. Therefore, it is legitimate to say that a contemporary practice of machines of wonder can critically reflect emerging cultural and philosophical concerns. Adopting this notion, this research further explores the characteristics of experience, potential of aesthetics, and media research tendencies involved in prototyping 21st century machines of wonder.

While these two questions have guided the whole research, there were also more specific concerns and interests addressed in each of the media experiments conducted. These are presented in the ‘developmental context’ section of each project.

1.4 Aims and Objectives

1.4.1 *Aims*

As a media practitioner, my primary aim is to construct a practice framework in the field of new media art and design that can be multi-disciplinary, reflective and productive in nature, and has potential implications for the relationship of humans and machines in the 21st century.

1.4.2 *Objectives*

The main objective of this study is to practically construct machines of wonder for the 21st century as creative media artefacts. Before that, this research needs to address the following objectives.

- It needs to identify the characteristics of machines of wonder by investigating what they were, are and can be. Emerging characteristics of computer-assisted fabrication should be reviewed for more insight.
- It speculates a critical framework for constructing machines of wonder in the 21st century and practising it reflectively.
- It gains feedback from exhibitions and documenting development of all proposed machines of wonder.
- The final objective is to produce a reflective writing piece that interlinks the conceptual background, media analysis, design aesthetics and technical developments, and provides critical insights, future possibilities and implications through these practices.

1.5 Methodology: A Practice-based and Pragmatist Approach

Conducting this research in Newcastle University's Culture Lab, one of the media labs in the UK that straddles different academic subjects and industry sectors (Frost, 2012), I adopted the flexible and interdisciplinary media-lab work style and conducted this research applying integrative approaches, methodologies and inquiries to the making of machines of wonder.

As my research aim shows a clear attempt to inform emerging technological and media practices, it is appropriate to adopt a practice-based methodology in which the claims of originality and contribution to knowledge may be demonstrated through and with creative outcomes (Candy, 2006; Seago & Dunne, 1999). The creative artefacts are placed at the centre of the thesis to form a systematic and original enquiry, which adopts the notion of "object as research discourse" or "material thesis" (Seago & Dunne, 1999, p.16). That is, the process of artefact making is considered a mode of material discourse (Seago & Dunne, 1999; Barad, 2003), through which this research forms a thematic analysis of the topic issues, largely based on artefact practice and insights. This concept identifies the limits of discursive language and

considers the practices of knowing, making and being as mutually implicated. Under the criteria of such practice-based methodology, this thesis will have an indexical relationship to the artefacts (Bowers, 2012). Critical analysis of theories and artworks are reflected both with making and through making. The thesis depends on traceable connections to the media projects for its significance, just as the media projects are illuminated through the thesis argument. In other words, all the experimental machines of wonder were created with a developmental context that links to the thesis inquiry, and served to provide insight through practice and reflection.

In order to identify the characteristics of machines of wonder, this research conducted two experimental projects as research ground work (discussed in Chapter 2), as well as analyzed the characteristics of automata and emerging digital technology (discussed in Chapter 3). These helped speculate a critical framework for constructing machines of wonder in the 21st century. In Chapter 4 and 5, two threads of Wundermaschinen making were explored reflectively. Each thread started with an experimental practice. The practice was accompanied by a media archaeological review on specific artefact in history. The reflection through making, the feedback from exhibition, and the media archaeological review then influenced later project development. This research documented all developmental process of each projects in order to provided critical insights, future possibilities and implications in the practice of Wundermaschinen.

This research's methodology is also influenced by a pragmatist approach in HCI. Recent literature of HCI explores 'enchantment' as an approach toward aesthetic interaction. Petersen, Iversen, Krogh & Ludvigsen (2004) suggest that there is a need for alternative frames of reference in interactive system design and alternative ways of understanding the relationships and interactions between humans and new digital technologies. Adopting Dewy's pragmatist

aesthetics, Petersen et al (2004) see aesthetics as a particular kind of experience that emerges in the interplay between context, user, culture and history. Aesthetic experience is thus not limited to the gallery or theatre, it can be the stuff of our everyday lives as lived and felt (Wright, Wallace & McCarthy, 2008). Drawing on such notion, HCI researchers suggest to understand people's interactions and relations with digital technology under three themes: 'a holistic approach', 'continuous engagement and sense-making' and 'a relational or dialogical view of experience' (Wright et al, 2008).

As suggested by Wright et al (2008), a 'holistic approach' suggests conceptualize experience with sensual, emotional, compositional and spatio-temporal threads . A 'continuous engagement and sense-making' suggests think of sense-making in terms of six processes: anticipating, connecting, interpreting, reflecting, recounting and appropriating. An approach of 'relational or dialogical view of experience' suggests the artefact as multi-perspective, open to change and ultimately unfinalizable. Based on these concepts, researchers like Wright et al (2008) suggest 'enchantment' as one variety of experience with technology that is central to aesthetic experience (McCarthy, Wright, Wallace & Dearden, 2006; Wallace, 2007).

Enchantment, for the authors, is:

“experiences such as being charmed and delighted, and carries with it connotations of being bewitched by magic and of being caught up and carried away. Interactive systems designed to enchant should offer the potential for the unexpected, giving the chance of new discoveries and new ways of being and seeing.” (Wright et al, 2008, p.10)

Reflecting the intention in HCI to seek enchantment and depth of the experience in digital technology, this research exploring machine of wonder adopts a method of developing media archaeology within artistic practice, and aims to document a dialogical and reflective process between the artist and audience. Some of the methods by HCI researchers were thus adopted.

For example, this research explores the ‘specific sensuousness’ of each particular project (Wright et al, 2008, p.10) by prototyping ‘mahcine of specific senuousness’ (explained in section 3.4.3.1) and by discussing each work with the audience for feedback. This research aimes to create ‘a sense of being-in-play’ (Wright et al, 2008, p.10) by prototyping ‘machine of curiosity’ (explained in section 3.5.6) that challenges the viewers’ familiar categories and values. This research sees the Wundermaschinen as ‘objects of paradox, openness and ambiguity’ (Wright et al, 2008, p.10) by suggesting Wundermaschinen as object of philosophical argument (in section 3.5.7). This research explores the ‘transformational character of experience’ (Wright et al, 2008, p.11) as a means to engender wonder, especially in the practice of Wundermaschinen of Correspondence in Chapter 4.

Therefore, reflecting on the enchantment literature in HCI, this research adopts a pragmatist methodology which aims to extends the rich cultural-historical and human-relational context of artefacts through utilizing digital making tools. A few sub-methods were utilized in this research to achieve this goal. These sub-methods will be utilized in each of the particular project (in the description of each specific art work):

1.5.1 *Contextual Review: Constructing a Practice Framework*

A contextual review was critical for developing a practice framework through literature, media artefacts analysis and contemporary artwork critique. In Chapter 3, a review of historical machines of wonder was conducted to critically investigate their overlapping similarities (in section 3.3). A review of computer-assisted machine prototyping in the emerging maker-culture was critical for proposing the experimental aspects (in section 3.4). Both these reviews embodied an intention to construct a conceptual framework for creative practice. Many contemporary artworks were also analyzed in different sections to clarify the practice framework. This method of contextual review served to keep this research informed

on the issues, studies and works of others and provide a framework to balance the thesis and the creative practice into a coherent body.

1.5.2 *Media Archaeology: Excavating the Unrealized Dreams*

The approach of media archaeology is drawn on in this research, with the intention to examine how present day machine prototyping can be richly informed by the machines of wonder of the past. Media archaeology, as a unique perspective toward media archiving, generally follows Michel Foucault's genealogy of knowledge in *Archaeology of Knowledge* (Foucault, 1970) and Friedrich Kittler's investigation of media and technology in *Discourse Networks 1800/1900* (Kittler, 1985). For my research, media archaeology is understood as a research orientation interested in the forgotten paths and the techno-historical cultures of past media. It aims to construct alternate histories of suppressed, neglected and forgotten machineries that do not point to the present media-cultural condition. In this study, media archaeology is a means to reveal wider context of understandings of specific motivation and background for which an artefact is constructed. For example, some automata will be examined in Chapter 3 to see how wonder may be created, and how automata have shaped human's wider understandings of cosmology and physiology of living things, as well as social and cultural understandings of what a society should be.

Therefore, my archaeology of machines of wonder, as suggested by Kluitenberg (2011), shifts attention away from a mere progressive history. Rather, it is an analytical approach that intends to show how particular informal genres, such as 'machines of correspondence' (which will be discussed in Chapter 4), were at work and shaped certain designs of machines of wonder.

In addition, recent studies by media thinkers have particularly shown an increasing ambition to develop the practical dimension of media archaeology (Hertz & Parikka, 2012; Zielinski, 2006; Kluitenberg, Zielinski, Sterling, Huhtamo, Carels, Beloff, Druckery & Akomfrah, 2007; Druckrey, 2006). As Timothy Druckrey points out in his foreword to Siegfried Zielinski's book *Deep Time of the Media* (2006):

“The mere rediscovery of the forgotten, the establishment of oddball paleontologies, of idiosyncratic genealogies, uncertain lineages, the excavation of antique technologies or images, the account of erratic technical developments, are, in themselves, insufficient to the building of a coherent discursive methodology.” (Druckrey, 2006, p.ix)

This, argues Parikka (2012), shows that media archaeology needs to articulate its relation to art and design practice more clearly. That is, media archaeology as “a method for doing media design and art” (Parikka, 2012; Hertz & Parikka, 2012). This notion proposes that media archaeology moves from a research agenda on the margins of media studies to being a widespread cultural and material practice. For Parikka and Hertz (2012), media archaeology is a potential orientation to creative material intervention, since:

“Media in its various layers embodies memory: not only human memory, but also the memory of things, of objects, of chemicals and of circuits.... Media is itself an archive in the Foucauldian sense, as a condition of knowledge, but also as a condition of perceptions, sensations, memory and time.” (Hertz & Parikka, 2012, pp.425–427)

My research adopted the method of media archaeology as an investigative orientation into historical technological media following a certain creative intention (e.g. to develop machines of wonder). The method is not to find historical narratives, but rather to excavate the unrealized or forgotten dreams, the impossible desires and the illogical solutions (Huhtamo,

1997; Kluitenberg, 2011) projected onto actual media machines, and investigate how these particular dreams and desires could be engaged through material interventions. This method intended to excavate and map, both contextually and practically, the layers of “mediation” (Bolter & Grusin, 2000) that could have shaped machines of wonder and informed experiences of such artefacts through key epochs in technological history. In my research, this archaeological orientation will not only work as a contextual background and source of inspiration in the speculation of 21st century machines of wonder (in Chapter 3), it will also critically integrate the conceptual framework, design aesthetics, means of prototyping and demonstration of media artefacts (in Chapter 4 and Chapter 5).

1.5.3 *Interdisciplinary Approach to Making: Art, Design and Engineering*

The interdisciplinary approach to making media artefacts adopted in this study was a hybrid of art, design and engineering. The art approach advocates the generative and improvisational perspective of practice and the projects are exhibited as a demonstration of outcome as well as an event for reflection. The design approach suggests all media experiments must go through a developmental process of production: from a developmental question, blueprint and material selection to design, demonstration and feedback. This approach embodies both traditional design criteria by starting with a sketch and schematic, as well as more emerging ways of prototyping such as computer-assisted fabrication and ‘open source making’ (which will be explained in section 3.4). The engineering approach includes hands-on circuit design, mechanical and electrical solution finding, and computational coding. The engineering approach also suggests that all media experiments are demonstrated and described only when fully-operating as they are specified to. The legitimacy of these multiple methods will be further justified in Chapter 3, where a review of the historical machines of wonder has revealed them to be objects of novel assembling skills and knowledge across disciplines (which will be explained in section 3.5.4).

1.5.4 *Reflective Prototyping*

As researchers have suggested (Scrivener, 2002; MÄ KELÄ & Nimkulrat, 2011; Holmes, 2006), practice-based research is conducted as an iterative process to create and critically reflect upon its research topic. Following this notion, my research adopts a method of reflective prototyping to document its iterative process of creation and reflection. In Chapter 2, two projects conducted in the early stage of this research will be annotated as a reflective space that guided work from general inquiries into more specific concerns. In Chapter 4 and Chapter 5, four experimental machines of wonder will be proposed, prototyped and exhibited for feedback and reflection. These pieces of feedback contribute to understanding of how the artefact is evaluated for further development. The reflection includes the project's direction changes, abandoned ideas, critiques, and breakthroughs that were made in consideration of potential meanings and contexts. What has been achieved and what future directions may be suggested will also be articulated.

In order to implement such methods of reflective prototyping, a website (Figure 4) was designed and published at the initial stage of this research (in Sep 2012). The website has acted as this research's platform for mutual "reflection-in-action" (Schön, 1983; Scrivener, 2002): I constantly re-consider past projects, re-contextualize annotations, document audience feedback and reflection, and share the exhibition images and publication documents. The website as a platform of reflective prototyping is particularly important as this research arrives at its final stage. It provides an overview of the experimental projects, thoughts, and direction changes.

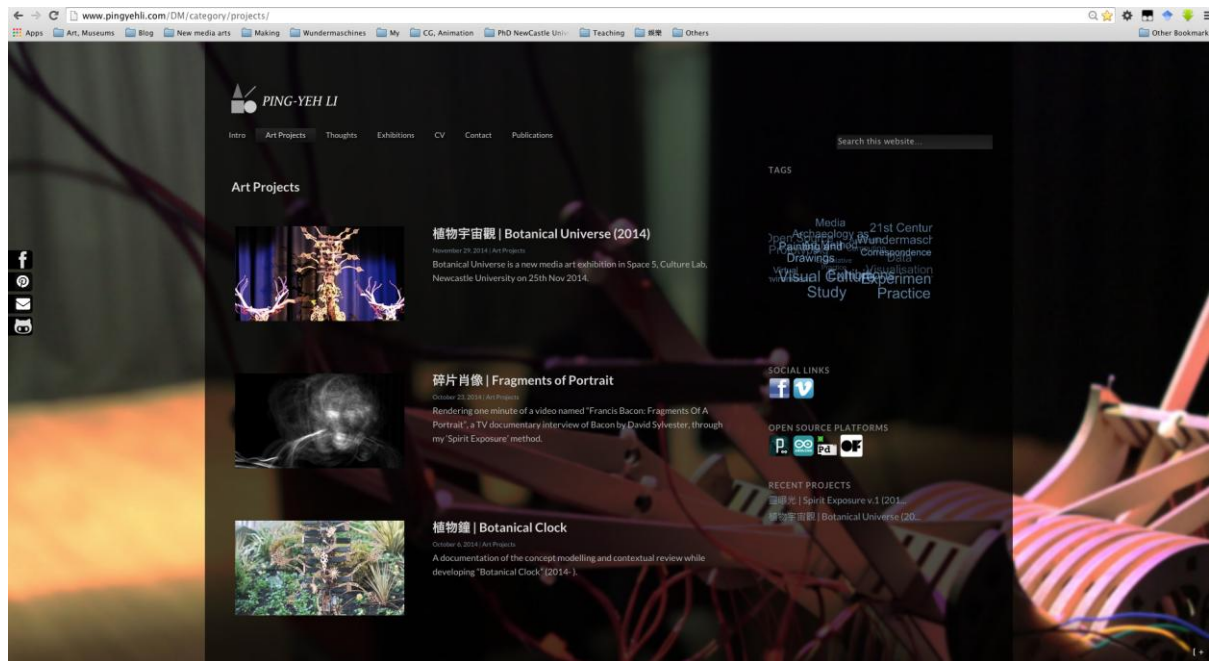


Figure 4 Website published for 'reflective prototyping' at: <http://www.pingvehli.com/>

Chapter 2 Information Visualisation and Wonder: Reflections through Early Projects

2.1 Introduction

This chapter will construct a ‘reflective space’ (as described in section 1.5.4) as two media experiments conducted in the early stages of this research are annotated and reflected on, to guide the research from general inquiries (as described in section 1.2) into more specific concerns. It was through this practice-led reflection, feedback and contextual review that more media archaeological and emerging material-oriented perspectives gradually came into focus. This chapter will show how the two projects were carefully considered prerequisites for later research, and how they underlay a continuity which could act as a creative drive for later machines of wonder.

2.2 Experimental Project: Sensing Energies (Sep – Dec 2012)

2.2.1 Methodology

As research groundwork, *Sensing Energies* explored alternative possibilities in the process of information sensing, receiving and visualising to what is commonly adopted in scientific visualisation. Embodied a notion of reflective prototyping (section 1.5.4) and practice-based experimenting, the making of *Sensing Energies* started with collaboration with computer scientists to experiment on how the massive sensor data flow could be retrieved, and how this data could possibly engender wonder in the audience. *Processing*, an Open Source tool, was utilized to enhance this process of collaborating and making-reflecting (see section 2.2.4 for more detail). *Sensing Energies* was displayed in a show in Culture Lab for feedback and

reflection (section 2.2.5). Based on the audience feedback and self-reflection, further implications will be given in section 2.2.6.

2.2.2 *Aims and Developmental Context*

Developed from September – December 2012, the *Sensing Energies* aimed to create a real-time information responsive experience by translating sensor-data flow into three-dimensional visual patterns. This piece was a collaboration with computer scientists based in Culture Lab and was demonstrated and exhibited at the *Work In Progress (W.I.P)* show in 14 Dec 2012 (see Figure 5 and Appendix 1). The Culture Lab *W.I.P* show is an annual event that highlights the lab's strong culture of experimentation, innovation and collaboration. Researchers are encouraged to share their ongoing design practice to gauge a broader range of responses.

Sensing Energies visualised six streams of environmental data: temperature, light, audio, PIR (passive infrared sensor), battery usage, and humidity, which were captured by forty-six sensors in the 2nd floor of the King's Gate Building in Newcastle University. According to the designer of the system, these sensors were installed to accurately predict the energy usage of the architecture and help develop a decision support tool to reduce energy consumption. It made the King's Gate Building one of the most prestigious smart architecture sites in the UK, which was able to provide better solutions for building energy output, efficient air-conditioning and an eco-friendly heating system. In order to examine the aesthetic potential of such system, *Sensing Energies* adopted "information visualisation" (Ware, 2004) as a creative tool to transform these massive data flows into visual experience.

2.2.3 *Design, Implementation and Aesthetics*

Sensing Energies explored alternative possibilities in the process of information sensing, receiving and visualising to what is commonly adopted in scientific visualisation. It did not apply means of visualisation that were “about diagrams and how they can convey meaning” (Ware, 2004, p.5) – no charts or graphs; nor did it aim to map attributes of the data into graphical primitives which effectively conveyed the informational content of the data. In other words, *Sensing Energies* moved away from a common logic of information visualisation, which mainly concerns information sampling and visual explanation, and intended to create an unusual experience that linked the audience’s visual perception to another physical space.

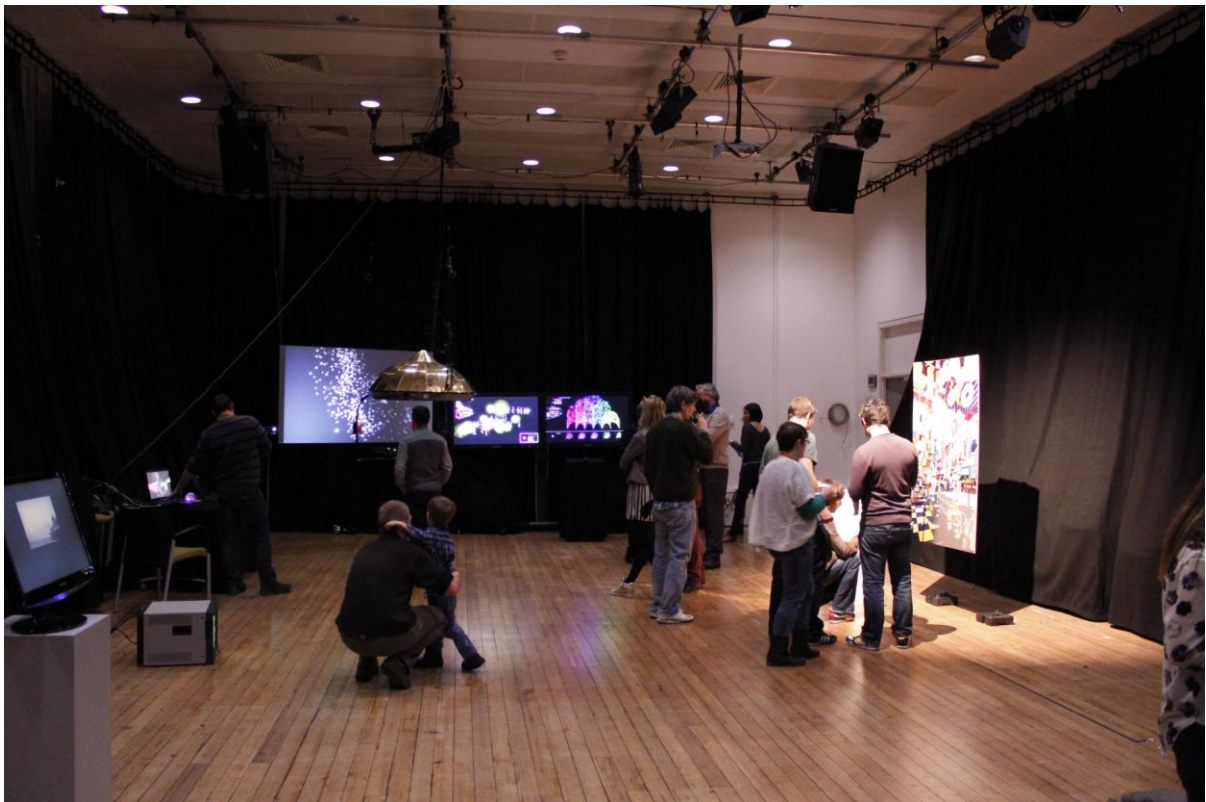


Figure 5 *W.I.P* show in Culture Lab, Newcastle University, UK, Dec 2012

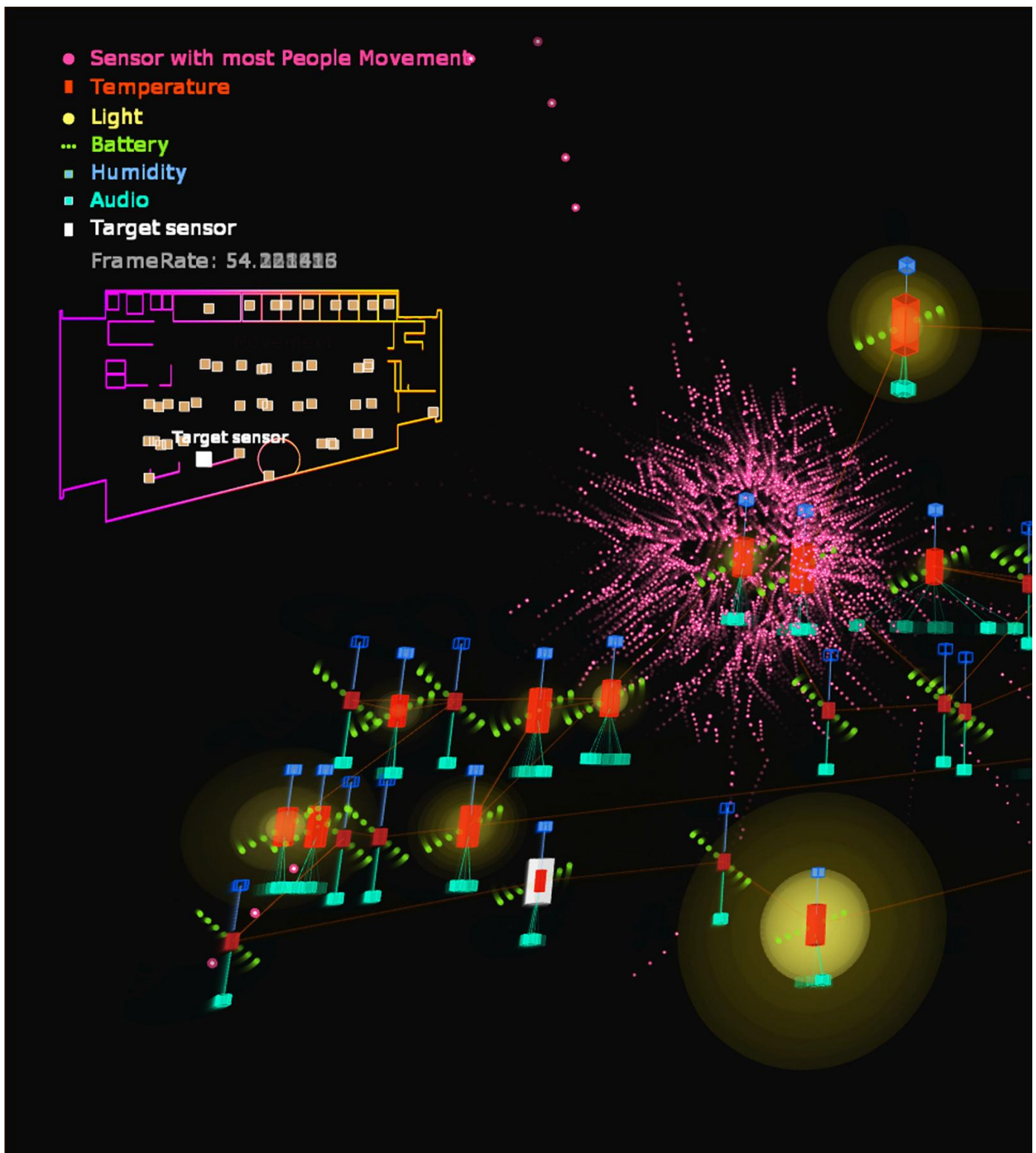
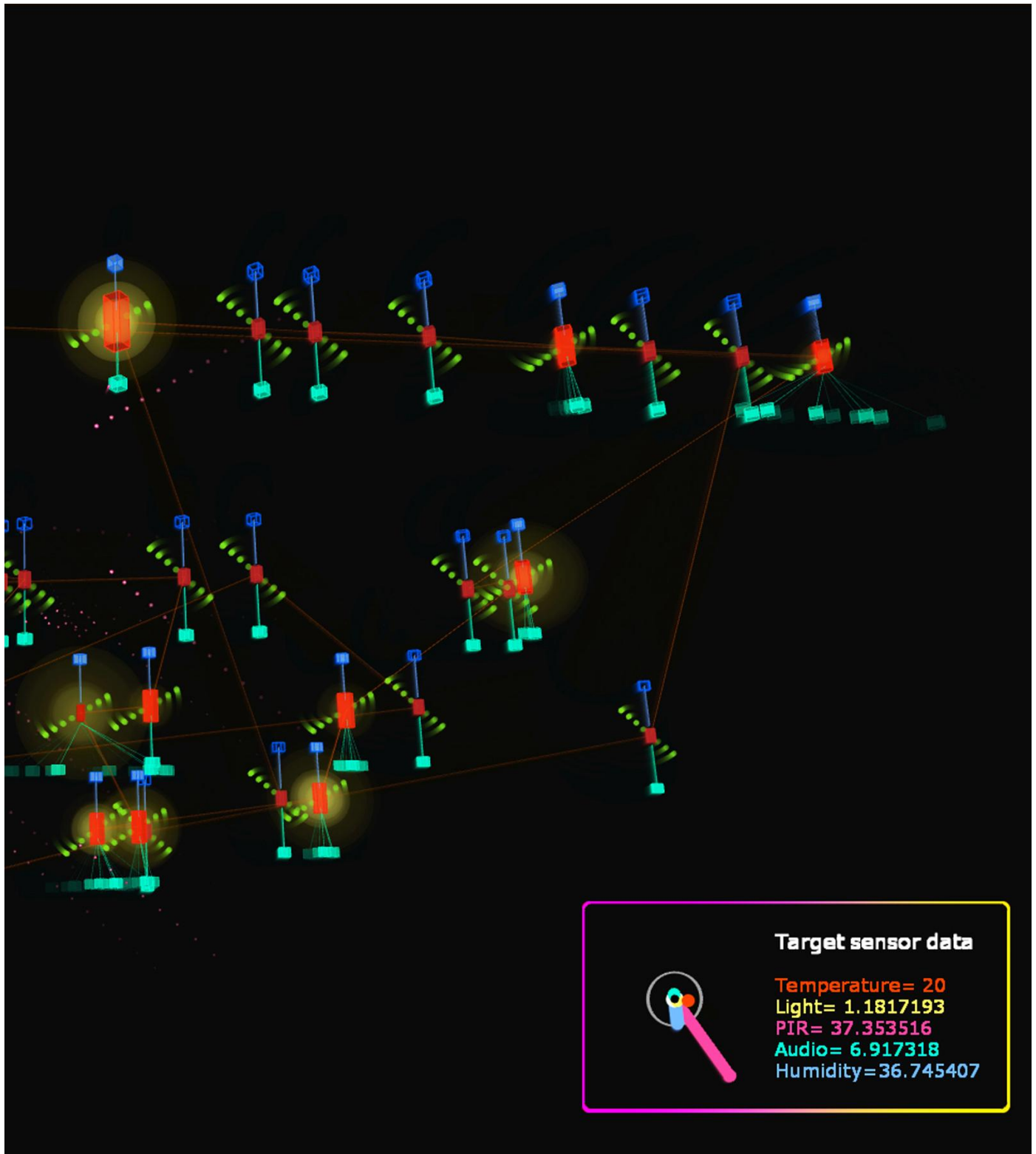


Figure 6 Visualisation of *Sensing Energies* (2012)



2.2.4 *Technical Description*

Sensing Energies was a piece of software coded in *Processing* (Shiffman, 2008a), which is a sketchbook-like coding language that has promoted software literacy within the visual arts. All the sensor-data were mapped to the screen according to their value, and displayed corresponding to their geographical position in the physical space. A floor map was shown on the left of the screen to inform the viewers of the actual architectural space. Some efforts were put into seeking a balance between an understandable and a provocative visualisation.

For its understandability, *Sensing Energies* represented different sensor-data streams by identifiable colours and formations. For example, bright yellow circles were used to represent the light information of each sensor while dynamic pink particles were drawn to locations with high human activity (PIR value). Brighter and bigger yellow circles represented higher light sensor-data. For its provocative-ness, a rather dense, vivid and complex visualisation was designed by displaying all information of the forty-six sensors simultaneously without reducing or sampling. This made *Sensing Energies* a real-time, dynamic and complex animation. In order to create a 3D space-like depth illusion, the virtual 3D camera (that creates the viewer's screen) drifted smoothly in circles and the work was displayed in a dark environment (see Figure 6 and Figure 7).

2.2.5 *Audience Response and Self-reflection*

Most of the audience members spent time exploring the details. Some people were amazed by how these sensor-data from another building could be brought into the exhibition space. Some showed more interest in talking about how the work was different from a common computational visualisation, as it was half-way between meaningfulness and confusion. A viewer suggested that this project be installed as a visual platform for the King's Gate Building Entrance. He said it might not make users aware of the building's energy saving as other

visualisation tools do, but could arouse more interesting discussions, such as issues of public-private information and how energy information could be transformed into a livelier experience. He also mentioned this work's potential as an urban design concept in 'public art' that concerned livability and sustainability (Miles, 1997, p.2).



Figure 7 Demonstration of *Sensing Energies* in W.I.P. show, Dec 2012

Despite the fact that most visitors showed interest from different perspectives, I realized many considered the work as a functional design piece, rather than a visual-aesthetic object. This reflected the fact that the work was similar to a monitoring screen and was quite limited in viewer-interaction and bodily experience. Some audience feedback suggested that *Sensing Energies* would have more potential if I could present a more physical experience or more direct contact between the viewers and another space. For example, one suggested creating illumination in the exhibition space that corresponded to the light quantity in the space in the

King's Gate Building. This feedback encouraged this research to explore how sensor values could be brought to physical world as experience.

On the other hand, *Sensing Energies* showed a strong creative drive. It demonstrated that I had already addressed the primary concern of making a visual-aesthetic object that is 'information-oriented' and has 'visual complexity' and encourages the audience to explore in detail (which will be further explained through literature reviews in section 3.5.2). *Sensing Energies* displayed less intention to raise critical issues of energy consumption, but rather provided the un-sampled mass of information for the viewers to explore with open-ended interpretation.

2.2.6 *Implications: Inquiries into the Potential Link between Information Visualisation and Wonder*

Sensing Energies has several implications for this research. Firstly, the limitation of this work as a visual-aesthetic object urged me to reconsider how computational information visualisation could be adopted as a critical tool to approach facets of wonder. For example, how could we create wonder in the viewers by means of information visualisation? What were the specific experimental aspects of the computational process that we could look for to inform machines of wonder? These questions were based on the fact that, ironically, emerging information visualisation tools are easy to obtain from the Internet and therefore the artist who works with computational information unwittingly shares a common logic with much explanatory visualisation work, and risks creating work that is too similar to utilitarian and explanatory objects. Instead, I aimed for an alternative relationship between the technological artefact and the viewer, which will later be informed by a review of the characteristics of canonical machines of wonder (in section 3.3).

These inquiries prompted this research to adopt the approach of information visualisation with alternative techniques, such as the physical, auditory and atmospheric dimensions of information visualisation. These inquiries guided me to explore more flexible means for generating, collecting and representing information as a more critical part of the installation and performance of machines of wonder, with the aim of distinguishing an approach from explanatory information visualisation.

2.2.7 *New Knowledge Occurred in the Making*

The making of *Sensing Energies* realized how to utilize a JSONObject and Gozorra library to retrieve the sensor data flow from Kings Gate Building in Newcastle University. This project also produced insight on how an object-oriented programming technique in *Processing* can facilitate artistic visual design. Please see Appendix 10 for more details.

2.3 Experimental Project: Spirit Exposure V.1 and V.2 (Nov 2012 – Jun 2013)

2.3.1 *Methodology*

Following the feedback of *Sensing Energies*, *Spirit Exposure* further explored how data could be collected on-site and how a computational process could transform daily experience into unusual images. Adopting methods of interdisciplinary approach to making (section 1.5.3) and reflective prototyping (section 1.5.4), the making of *Spirit Exposure* aimed to explore the juxtaposition of identities between the engineer, psychic and magician through practice; and investigate how wonder could be created through presenting a techno-historical relationships between media. *Processing* was utilized in this project as there were a few libraries that could be directly imported for image rendering (see section 2.3.4 for technical detail). *Spirit Exposure* was displayed in seminars for feedback and reflection (section 2.3.5). Based on such feedback and reflection, implications will be given in section 2.3.6 and 2.3.7.

2.3.2 *Aims and Developmental Context*

On the basis of this experience with *Sensing Energies*, *Spirit Exposure V.1* and *V.2* were developed. Created in November 2012 – June 2013, *Spirit Exposure V.1* explored how an imaginative notion of ‘capturing spirit’ could be embodied in image processing through computer coding. This work extended the intention in the previous project *Sensing Energies* (2012) to examine the transference of spatial qualities (temperature, light, humidity) into visual experience. Supported by the feedback and reflections of previous project, *Spirit Exposure V.1* further explored the intention of visualising information in a real-time setting by capturing and rendering the images on-site using a laptop camera. These images were displayed at the *Digital Media Seminar* in Culture Lab, Newcastle University on 25 Apr 2013 and at a workshop in Da-Zhen University of Technology, PingTung, Taiwan on 23 Dec 2014 for discussion and feedback.

2.3.3 *Design, Implementation and Aesthetics*

Spirit Photography is a genre of photography that mainly attempts to capture images of ghosts or other spiritual entities. Reflecting back to the notion of *Spirit Photography* in the 1860s (Kaplan, 2003), *Spirit Exposure V.1* was conducted with the particular intention to see how the media practitioner could become a ‘spirit photographer’, a hybrid being that is half psychic and half engineer. In order to achieve this, *Spirit Exposure V.1* speculatively questioned: How could the camera be technically ‘haunted’ through computer coding and what images could this approach produce? Could we turn the information collected into something more wondrous? Some experiments were conducted to see if we could create a wondrous image with visual complexity by infusing the techno-historical notion of *Spirit Photography* with information visualisation.

2.3.4 *Technical Description*

Spirit Exposure V.1 (Nov 2012 – Feb 2013) was also developed in *Processing*. It was a piece of software that compared the present camera frame with the previous one, and identified different pixels between the two frames. The positions of these different pixels were then mapped to an empty dark canvas. The brightness of each position incremented until it reached the brightest value of 255. Frame by frame, each pixel of the canvas gradually became brighter depending on how many times the pixel had been different since the camera started running. In this way, only the moving objects (such as pedestrians in an outdoor scene) could cause the image to expose. The detail of the moving objects stayed invisible since only the motional traces were exposed. All the images were captured and rendered on-site in public spaces during the day, including Northumberland Street and Central Station in Newcastle, UK (Figure 8, Figure 9 and Figure 10). The images were intentionally rendered as dark, negative-film-like images to show a different visual quality from historical light exposure photography.

Spirit Exposure V.2 (February 2013 – June 2013) was later developed into a series of short animations (Figure 11 and Appendix 2). The motion was rendered into colours, which mapped the changes of pixels into different tones. The colourful images were then sequenced and rendered into animation. The work involved a collaboration with German musician Annika Hass, who produced a music piece that combined the soundscapes of Newcastle with some live piano playing.

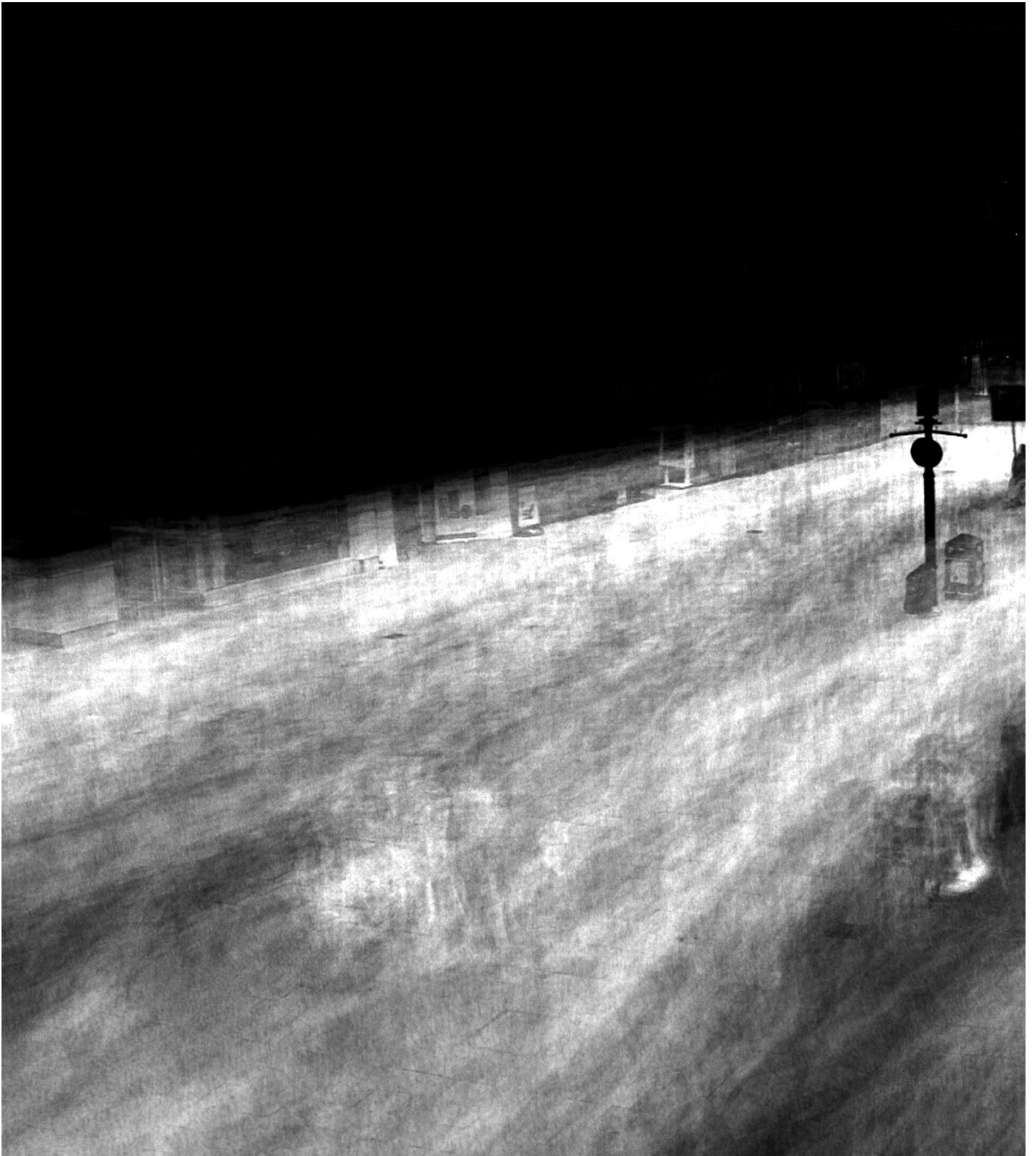
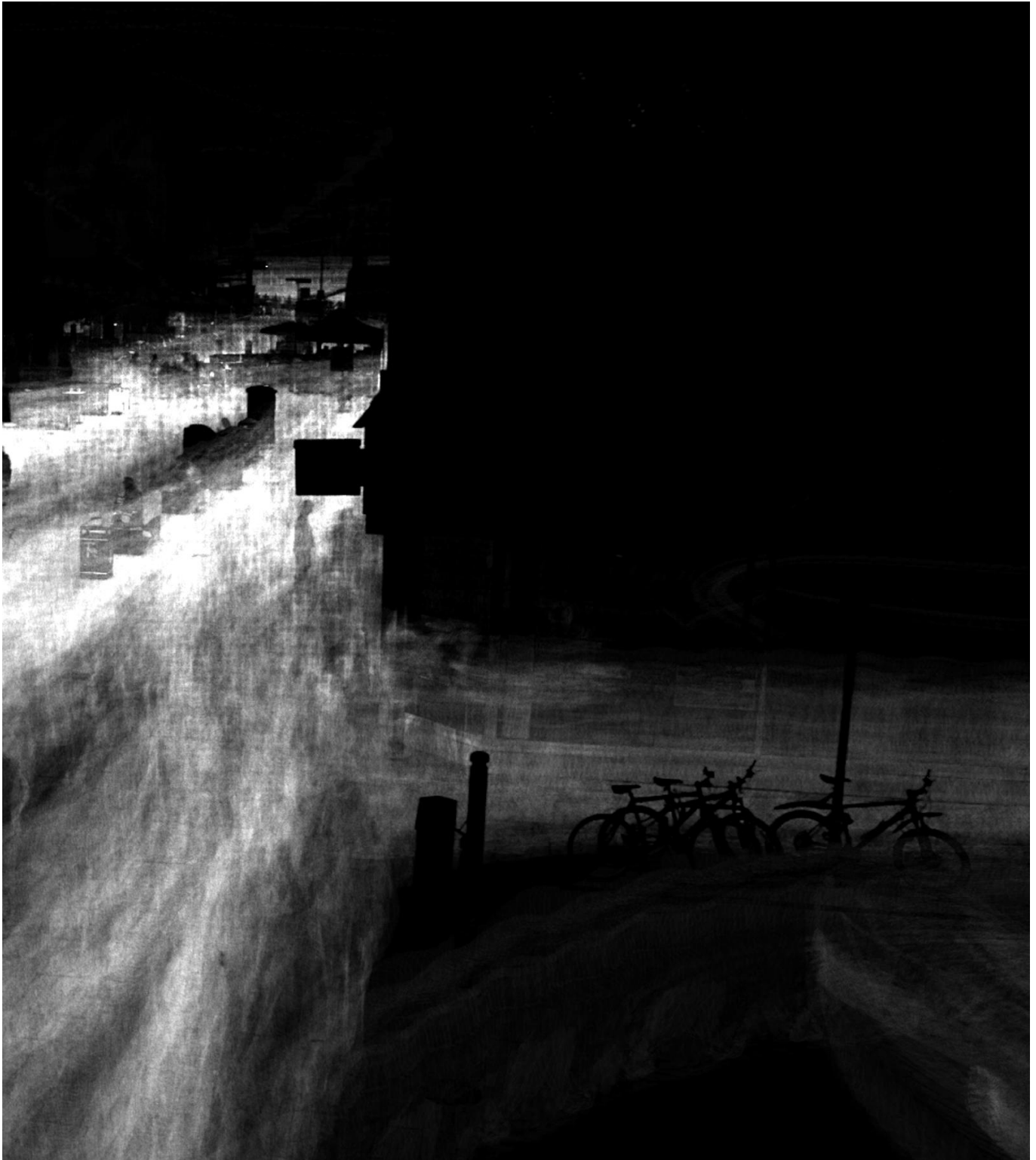


Figure 8 *Spirit Exposure V.1* image captured in Northumberland Street, Newcastle, UK, 2012



2.3.5 *Audience Response and Self-reflection*

Participants in the *Digital Media Seminar* were intrigued by the *Spirit Exposure V.1* images and wondered how these images were processed. Many did compare this project with the approaches and visual aesthetics of spirit photography and acknowledged the shared interests of revealing the unseen through emerging technological apparatus. Some considered *Spirit Exposure V.1* as successful in the way it attracted the viewers: the work somehow created wonder about how the image was composed and the potential transcendence of human sensitivity through the experience of technology.



Figure 9 *Spirit Exposure V.1* image captured in Northumberland Street, Newcastle, UK, 2012



Figure 10 *Spirit Exposure V.1* image captured in Central Station, Newcastle, UK



Figure 11 *Spirit Exposure V.2* animation still image, originally captured in Northumberland Street, Newcastle, UK, 2013

Spirit Exposure V.1 was linked by one audience member to the work of Martin Howse who showed a similar alchemical identity. For example, *A Return to the Earth* (2015) (Figure 12) left a laptop on the ground of a forest to return a series of electrical impulses from the hard disk into the earth through differentials induced between two metal plates that were inserted into the ground. This process of “returning memory to the earth” (Howse, 2015) lasted for one hundred and seventy five days, until the informational content of the hard disk had been exhaustively returned to the earth. Comparing my work to Martin Howse’s, the audience feedback acknowledged that there was a shared spiritual or alchemical perspective on human-computer interaction; and through practice the recall of historical notions (of alchemy or esotericism) in the computational might generate critical outcomes.

2.3.6 ***Implications: Media Practitioner as Engineer, Psychic and Magician***

The practice of *Spirit Exposure* had two critical implications for this study. Firstly, the juxtaposition of identities by creating an esoteric vision through a computational mechanism re-affirmed the overlapping identity of engineer, psychic and magician mentioned by Zielinski (Zielinski, 2006, pp.277–278) and raised questions of how this mixed identity could be explored with information visualisation. The apparatus operator or computer coder somehow merged with the character of stage magician by an alternative technique of information collecting and representing – in *Spirit Exposure*’s case, through the superimposition of natural motions onto real-time rendering images. This notion was considered critical as it offered creative alternatives to information visualisation techniques.

A later version of *Spirit Exposure* reflected on this experimental notion of the coder as psychic. A video documentation of British painter Francis Bacon, rendered by *Spirit Exposure* mechanism, was paralleled with his *Three Studies for a Self-Portrait* (Figure 13). One minute

of *Francis Bacon: Fragments of a Portrait*, a TV documentary interview with Bacon by David Sylvester, broadcast on BBC on the 18 September 1966, was processed into an image (Figure 14). This experiment further explored this engineer-psychic-magician identity with specific interest in how the computationally rendered images could trigger wonder by a comparative approach to a more traditional media image (such as lithography). In Chapter 3, this notion of ‘juxtaposing the contemporary and the techno-historical’ for the creation of wonder will be further discussed in relationship to existing literature.



Figure 12 Martin Howse (2015) *A Return to the Earth*



Figure 13 Francis Bacon (1979-1980) *Three Studies for a Self-Portrait*, lithograph printed in colours on Arches paper, 47 x 103.5 cm



Figure 14 A later version of *Spirit Exposure* that renders one minute of a video “*Francis Bacon: Fragments of a Portrait*”, a TV documentary interview of Bacon by David Sylvester, broadcast on BBC1, 18 September 1966

2.3.7 *Implications: Techno-historical Relationship and Wonder*

As mentioned earlier, the audience feedback on the juxtaposition between *Spirit Exposure* and spirit photography suggested how wonder might be achieved through presenting a historical relationship between technological media. By historical relationship, I mean to utilize contemporary technology with a cultural-historical or techno-historical orientation, such as the juxtaposition of information visualisation and monochrome photography. In this sense, the contemporary technology must be presented in a specific way to connect, re-call or re-imagine the past. This implication guided this research to conduct literature reviews (in section 3.3) adopting notions of media archaeology and to locate similarities between historical and contemporary machines of wonder.

2.3.8 *New Knowledge Occurred in the Making*

The making of *Spirit Exposure* proved how potential it is to play and experiment with the example code provided by the *Processing* developers and communities. New experience and interesting outcome may occur in the process of experimentations, or simply through a copy-and-paste strategy. The making of *Spirit Exposure* suggests that the maker/artist not necessarily starts from scratch in design. Otherwise, it encourages the maker/artist to explore the interesting alternatives through re-editing other's code or example. Please see Appendix 11 for more details.

2.4 **Specific Concerns toward Machines of Wonder**

Feedback on and reflection of the two early projects were considered vital in how this practice-based research developed from the general research questions to more specific concerns. What was of focus in *Sensing Energies* and *Spirit Exposure* was not inquiries of “aesthetic information-visualisation” (VandeMoere, 2008; Zhao & Moere, 2008), which covers discussion of how information can be perceived understandably and at once

visual-aesthetically. Neither was it exploration of “data physicality” (Moere, 2008), which concerns pushing data communication outside of the digital screen (VandeMoere, 2008, p.473). Rather, my study concerned an experimental inquiry into how a speculative identity of the media practitioner (engineer-psychic-magician) could profoundly influence the prototyping and experience of the technological artefact. It embraced a wider potential of viewer interaction and suggested applying multiple techniques and material formations. This research’s specification of research questions through a practice-based inquiry has similarities with anthropologist Tim Ingold’s (2013) “the art of inquiry”.

“In the art of inquiry, the conduct of thought goes along with, and continually answers to, the fluxes and flows of the materials with which we work. These materials think in us, as we think through them. Here, every work is an experiment: not in the natural scientific sense of testing a preconceived hypothesis, or of engineering a confrontation between ideas ‘in the head’ and facts ‘on the ground’, but in the sense of prising an opening and following where it leads” (Ingold, 2013, pp.6–7)

In Ingold’s (2013) words, this research’s ground work on machines of wonder through practice should be taken as an act of meshwork weaving (Ingold, 2013, p.132), which elucidates specific interests and exemplifies the idea that my research is largely grounded on an anthropological notion that “is studying with and learning from; it is carried forward in a process of life, and effects transformations within that process” (Ingold, 2013, p.3). This research reflects Ingold’s attempt to “move forward” (Ingold, 2013, p.7), in that exploring the machine of wonder is to open up our perception to what might be going on so that we, in turn, can respond to it. Therefore, I proposed the following specific concerns toward machines of wonder:

- This research’s media practices should move away from scientific and explanatory means of

information visualisation, and otherwise explore alternative potential for experience, particularly concerning how information could be generated, collected and represented. This research will explore the ‘information-oriented’ aspects of computational artefacts (in section 3.4.3).

- There are ‘performance-like’ aspects in artefacts of information processing and transformation and they should be a focus of exploration (which will be further discussed in section 3.5.3)
- The primary concern of the visual-aesthetics of my media experiments is to produce objects that are ‘information-oriented’, dynamic and have ‘visual complexity’ that encourages the audience to explore further (which will be discussed in section 3.5.2).
- An identity of media practitioner as engineer-psychic-magician is considered to have potential, and will be further adopted in future media experiments. This identity will be explored through literature review of historical machines of illusion and trickery (in section 3.3.4) and media practices of *Experiential Converter* (annotated in section 4.6) and *Botanical Universe* (annotated in section 5.6).
- To focus on, or reveal, how techno-historical relationship between new and past media might be a critical route toward machines of wonder (which will include reflection on the media archaeology of ‘unrealized dreams’ in historical machines of wonder in Chapter 4 and Chapter 5).

In addition, adopting the method of ‘reflective prototyping’ (section 1.5.4) and Ingold’s art of inquiry, the two projects critically documented and reflected on the emerging characteristics of technology that could engender curiosity. This notion of technology of curiosity is

considered important, as a passage in *Commentary on the Metaphysics of Aristotle*

(Greenblatt, 1990) illustrates:

“Wonder is ... a constriction and suspension of the heart caused by amazement at the sensible appearance of something so portentous, great, and unusual, that the heart suffers a systole... Such is the origin of philosophy.” (Greenblatt, 1990, p.34)

Greenblatt (1990) argues that a relationship of wonder implies to doubt, to ask questions and to allow the viewers to peer into worlds beyond their normal senses, to bring together patterns beyond their normal recognition, and, in so doing, to enlarge the world they live in. This form of relationship thrives on imagination and aims to open up new perspectives, to create spaces for discussion and debate about alternative ways of being, and to inspire and encourage the viewer’s imagination to flow freely. This notion of ‘machinery of curiosity’ will be further discussed in section 3.5.6.

The practice of *Sensing Energies* and *Spirit Exposure* inclined this research toward a concept of machine of wonder as this might particularly embody the multi-disciplinary nature and the unique knowledge connecting system of new media practices. They aimed to create an experiment framework where art/design, science/pseudo-science and art/technology are not contradictions. To do this, obviously, we need more pluralism in art, engineering and design, not only of visual style but also of ideology, techniques and values. This notion will be explored in the next chapter, as canonical machines of wonder and experimental aspects of computational media will be reviewed through existing literature.

Chapter 3 Speculations: Canonical Wundermaschinen and Contemporary Machine Prototyping

3.1 Introduction

In this chapter, I will review historical machines of wonder and contemporary features of artefact prototyping to draw out some design attributes for practice. In overview, section 3.2 will review the shifting idea of wonder in history. Section 3.3 will examine the historical machines of wonder constructed between the sixteenth and nineteenth centuries. Three groups of artefacts are discussed: ‘Metaphorical Artefacts’, ‘Mimetic Motions’ and ‘Mechanisms of Illusion and Trickery’. Section 3.4 will review the features of creative machine prototyping in the contemporary maker-culture such as computer-assisted fabrication and open source making. I will analyze their corresponding experimental aspects and potential in relation to this research. Section 3.5 will look at the above two analyses and draw out the family resemblances between these historical artefacts and contemporary media practices. Section 3.6 is a summary of this chapter, speculating on a ‘21st century Wundermaschine’ and illustrating how it can be materialized and experienced.

3.2 Wonder: A Brief Historical and Cultural Analysis

To situate the concept of wonder within new media art practice, it will be useful first to review the historical concept of wonder and explore its function in the development of aesthetic theory and the sublime.

3.2.1 *Wonder and the Birth of Philosophy*

One of the earliest disciplinary claims for wonder unfolds in Plato's dialog *Theaetetus*. The sensation and experience of wonder, Socrates explains, "is the feeling of a philosopher, and philosophy begins in wonder" (Plato, 2009). However, the wonder Plato speaks of there is wonder in the sense of puzzlement or perplexity, not in the sense of awe or curiosity. Wonder by Socrates is the mark of the philosopher. In the dialogue between Socrates and Theaetetus², we have seen that wonder arises when something that seemed reasonable and self-evident becomes strange and insupportable.

The second classic case for the Western discussion of wonder occurs at the beginning of Aristotle's *Metaphysics*. The context of discussion is similar – wonder again signals the origin of philosophical inquiry in ignorance:

"For it is owing to their wonder that men both now begin and at first began to philosophize; they wondered originally at the obvious difficulties, then advanced little by little and stated difficulties about the greater matters...therefore since they philosophized in order to escape from ignorance, evidently they were pursuing science in order to know, and not for any utilitarian end. " (Aristotle, 2009)

Following Aristotle, in the thirteenth century, Albertus Magnus and Roger Bacon both discussed wonder and its relation to ignorance (Mansfield, 2007, p.160). According to these principal ancient sources, wonder is induced by direct observation, leading from the acknowledgement of ignorance to the pursuit of knowledge without any utilitarian end.

• ² Socrates asks Theaetetus, "Tell me, Theaetetus, in reference to what I was saying, are you not lost in wonder, like myself, when you find that all of a sudden you are raised to the level of the wisest of men, or indeed of the gods? -for you would assume the measure of Protagoras to apply to the gods as well as men? Theaetetus replied: "Certainly I should, and I confess to you that I am lost in wonder. At first hearing, I was quite satisfied with the doctrine, that whatever appears is to each one, but now the face of things has changed" (Plato, 2009).

Wonder thus relates to the origin of philosophy as it begins in being puzzled by something and wanting, and therefore searching; to be no longer puzzled by it. Wonder gives birth to a longing for clarity, which may come from further exploration, or a rethinking of what one think one knows.

3.2.2 *Wonder as a Wide Spectrum of Emotions*

John of Damascus, writing in the eighth century, served as an important source for the typology of contradictory emotions associated with wonder (Mansfield, 2007, p.160). In the seventeenth century, French philosopher René Descartes describes wonder as one of the primary emotions since he claims that emotions in general are reactions to unexpected phenomena. In *Les passions de l'âme*, it is with the six primary passions (wonder, love, hate, desire, joy and sadness) that Descartes begins his investigation on their physiological effects and their influence on human behavior. Descartes notes that when people first encounter a surprising or new object, it makes people wonder and be astonished at it. Descartes therefore propounded that “wonder is the first of all the passions” (Descartes, 1649, Article 53). However interestingly, Descartes held a fundamentally negative view of wonder:

“It’s good to be born with some inclination to wonder, because that increases scientific curiosity; but after we have acquired some scientific knowledge we should try to free ourselves from this inclination.” (Descartes, 1649, Article 76)

Descartes suggests that wonder can be harmful. Excessive wondering can block the use of reason. For those who lose wonder, Descartes suggests to “make up for the loss of wonder through a special state of reflection and attention that we can voluntarily impose upon our understanding” (Descartes, 1649, Article 76). As for excessive wondering, Descartes suggests

to “acquire knowledge about many things and to deal with things not by wondering at them but by examining them” (Descartes, 1649, Article 76).

In Lorraine Daston and Katharine Park’s wide-ranging study of the history of wonder, the authors are suspicious of grand narratives, preferring to approach wonder as a set of “sensibilities that overlapped and recurred like waves” (Daston & Park, 1998, p.11). Daston and Park (1998) suggest that from at least the twelfth century, the terms for wonder in Latin and the Romance languages had a well-developed profile. Wonder in their literature was capable of arousing a wide spectrum of emotional tones or values, including fear, reverence, pleasure, approbation and bewilderment. In the late fifteenth or sixteenth centuries, these different flavors of wonder acquired different names, for example, *admiration* and *astonishment* in English, *Bewunderung* and *Staunen* in German, and *étonnement* and *admiration* in French.

Daston and Park (1998) claim that the multiplication and refinement of vocabulary of wonder signals the prominence of the passion and its nuances in the early modern period. Wonder was from at least the High Middle Ages a well-defined but also an extraordinarily rich and complex emotion. The tradition had a strong coherence, which rested in both the objects of wonder and the passion that they inspired (Daston & Park, 1998, p.16). Wonder, in this sense, is an overlapping and recurring sensibility of human beings, capable of arousing a wide spectrum of emotional tones or values. Temporary speechlessness, incomprehension, astonishment, delight, agony, fear: bodily states that exceed the moderation of the senses or push sensation into extreme states, were associated with wonder.

3.2.3 *From the Observing Subject to the World Observed*

As Mansfield (2007) suggests, since the medieval period, the condition of wonder was also transposed from the observing subject to the things observed, especially in travel literature, topographical writings, and catalogs of marvelous places, buildings and things. For example, the emphasis in thirteenth and fourteenth century travel literature was on the role of the eyewitness and the exotic circumstances that induce wonder (Mansfield, 2007, p.160). The Far East was typically filled with wonders or marvels. In the following few centuries, the fantastical experiences that John Mandeville and Marco Polo described were also transposed to the margins of the so-called New World in the age of discovery:

“The New World seemed timeless, secure, and miraculous, a haven for the suffering and distressed. Its climate was temperate and not subject to extreme and uncertainties... It allowed for the miracle of resisting disease and old age, and cleansed souls of moral corruption.” (Najmuddin, 2005, p.19)

The wonders in travel literatures prepared men for the idea that paradise was a terrestrial island, and further influenced Christopher Columbus’s voyages which initiated the early European colonization of the New World (Najmuddin, 2005, pp.17–20).

3.2.4 *Wonder and Aesthetics of the Sublime*

Aesthetics includes the capacity to sense, appreciate, and respond emotionally to beauty in both human creations and the natural environment (Kemple & Johnson, 2002). In aesthetics, the sublime is the quality of greatness, whether physical, moral, intellectual, metaphysical or spiritual. The term of sublime especially refers to greatness beyond all possibility of calculation, measurement, or imitation. German philosopher Immanuel Kant, in 1764, made an attempt to record his thoughts on the observing subject’s mental state in *Observations on the Feeling of the Beautiful and Sublime*:

“It is Kant, likewise, who made of the sublime – that strain of wonder that became a centerpiece of Romantic experience – one of the most telling moments of his aesthetics.” (Vasalou, 2012, p.27)

In this book, Kant suggests there are two kinds of finer feeling: the feeling of the beautiful and the feeling of the sublime. Some of Kant’s examples of feelings of the beautiful are the sight of meadows strewn with flowers and the valleys with winding brooks (Kanter, 2011, p.15). Feelings of the sublime are the sight of raging storms, mountain peaks, and the depiction of the kingdom of hell (Kanter, 2011, p.14). For Kant, feelings of the beautiful is a pleasant sensation but one that is joyous and smiling. Feelings of the sublime arouse enjoyment but with horror.

In his 1790 book *Critique of Judgment*, Kant further notes that beauty is connected with the form of the object, having boundaries, while the sublime is to be found in a formless object, represented by a boundlessness (Kant, 1914, pp.101–102). For Kant, one’s inability to grasp the magnitude of a sublime event such as a sight of mountain peak demonstrates inadequacy of one’s sensibility and imagination. Simultaneously, one’s ability to subsequently recognize such a phenomena as singular and whole indicates the superiority of one’s cognitive, supersensible powers. Therefore, for Kant, it is this “supersensible substrate” (Kant, 1914, pp.41, 117, 233, 234), underlying both nature and thought, on which true sublimity is located.

As Prinz (2013) suggests, Kant’s theories have roots in eighteenth century Empiricist aesthetics, which emphasizes emotional responses that are distinctive of art. Such aesthetic theories suggest art aspires to sublimity and induces majestic emotions, such as awe, wonder, and fear (think of Edmond Burke’s terror as the ruling principle of the sublime). In his 1818 work *The World as Will and Representation*, German philosopher Arthur Schopenhauer

further considers “aesthetic contemplation” as a temporary way for the human to escape from the pain caused by desiring, willing and craving. Art for Schopenhauer is a refuge from the illusory tricks of civilization and stops one perceiving the world as mere presentation. Art’s essential role is therefore “to enable us to escape what we already intuitively know about the irredeemable nature of what we are” (Bowie, 2003, p.262). Such notion of ‘art as sublimation’ suggests that individuals can distance themselves, refocusing energy toward positive ones, by looking at their existence from an aesthetic point of view. The encounter with artwork awakes special feelings in individual, which are crucial for evaluation and essential to art.

3.2.5 *Technological Sublime*

In the late nineteenth and early twentieth century, an awe and admiration for functionalism and streamlined forms in machines has been clearly noted by historians (Schaefer, 1970). This so called era of Machine Age celebration of the machine is considered by scholars an aesthetic movement. American and European art and design in this era reflected the proliferation and primacy of the machine. The machine aesthetics was promoted by those who saw beauty in the machine – a beauty in appearance and function. This fascination with the machine and industrial production was accompanied by an increase in visits to factories, as well as by the production of countless stereographs depicting factories and plants. This is considered to have influence on Dystopian movies (Telotte, 1999), Bauhaus style (Banham, 1980), Steampunk aesthetic (Miller & VanRiper, 2011) as well as Modern Arts such as Cubism and Futurism.

In *American Technological Sublime*, Nye (1994) discusses the development of a reverence for machines themselves and an understanding of the industrial environment as a new landscape to appreciate. Nye stresses the historicity and the politics of sublime experiences, presenting them as “emotional configurations that both emerge from and help to validate new social and

technological conditions” (Nye, 1994, p.xvii). He suggests that the emergence of new forms of the sublime should be considered not as absolute categories of aesthetic experience, but as contingent categories within social and political systems (Nye, 1994, p.xvii).

In the 1990s, Italian philosopher Mario Costa also defined a more comprehensive, aesthetic and philosophical theory of new media, which he named the “technological sublime” (Costa, 1994). For Costa, the concept of the sublime should be examined first of all in relation to the epochal novelty of digital technologies and technological artistic production (Salvini, 2004). Costa suggests that the traditional categories of aesthetics (i.e. beauty, meaning, expression and feeling) are being replaced by the notion of the sublime, which after being “natural” in the eighteenth century, and “metropolitan-industrial” in the modern era, has now become “technological”. According to Costa, new technologies imply on the one hand the weakening of the subject and the disappearance of the art and of all related categories. On the other hand, new technologies are at the origin of a new aesthetic dimension, the technological sublime (Costa, 1994). The technological sublime is defined by new categories of “the hyper-subject, the de-subjectivation of aesthetic production, and the suppression of the symbolic and the meaning” (Salvini, 2004). Costa also suggests that the traditional aesthetics developed from the eighteenth century, has become completely obsolete and useless to understand the present manifestations of art.

3.2.6 *Concept of Wonder: A Complex and Shifting Idea*

As the above review shows, the concept of wonder is “shifting its contents and its meaning in innumerable ways” (Daston & Park, 1998, p.17). The most enduring characteristic of wonder is that it defies stable classification. Wonder is in nature a coincidence of marvel and dread, amazement and terror. Wonder, on the one hand, is a subjective response to the sublime of nature and art that elicits pleasure. On the other hand, it is a monstrous and grotesque object

that elicits terror. For this research, the shifting concept of wonder may suggest that the emerging techno-anthropological condition and its most significant aesthetic products need a new explanation and theory. The exploration of technological wonder, reflecting Costa's (1994) notion, is a search of technological aesthetic fluxes. In the following sections, the idea of machine of wonder will be further explored through a media-archaeological approach—by looking at specific artefact in history, this research aims to excavate the characteristics of machine of wonder.

3.3 A Review of Canonical Wundermaschinen

In this section, I am going to conduct historical study, not in order to modify other designs, but to put this practice-based research in contact with historical investigation. It will specifically review three groups of automata that are often referenced as artefacts that possess intimations of wonder in cultural and historical studies of technology. I am not offering a strict typology, because these automata suggest overlapping similarities and tendencies, and it is very possible that a single automaton can present different aspects. For clarification of this media archaeological intention, from this point onwards this thesis will start using the German term 'Wundermaschine(n)' more often instead of 'machine(s) of wonder'.

3.3.1 *Automata as Models of Cosmology, Physiology and Society – A Media*

Archaeological Perspective

Concerned this research's aims to juxtapose media archaeology and new media practice as a coherent whole, it is critical to adopt media archaeology as a means to understand wider context of understandings for which an artefact is constructed. Automata, in this sense, are considered creative models of cosmology, physiology and understandings of human society.

Automata derived from the Greek word *automatos*, which means having one's source of motion within oneself. Automata are artefacts that shared one of the principle characteristics of living things – independently self moving. In this sense, automata appear to bridge the gap between the artificial and the natural, between artefact and organism. Because of this strange character, automata have received the attention of artists, cosmologists, and philosophers throughout the history.

In ancient Greece, some of the earliest automata inspired the first efforts to develop a mechanistic theory of living things, as well as Aristotle's attempt to distinguish between mechanism and the teleological character of organisms. From the late Middle Ages, many clocks also acquired automata, which moved in a lifelike way, showed the central role of harmony and symmetry for cosmologists. The Copernican cosmos, a harmoniously designed clock, suggested that heliocentric harmony was the musical and political consonance of parts in their proper places in a whole (Porter &Teich, 1992, p.104). The universe was considered a harmonious system drew upon teleological principles in nature. Later, Kepler's astronomy removed alchemical-astrological animism and mechanized the heaven as clock. For his system of the world, Kepler employed metaphors not only of musical but also of political harmony. The teleological domain of harmonic proportions drew mechanical laws into a systematic unity and provided the link between the spiritual and the material (Porter &Teich, 1992, p.105).

In Renaissance literature, automata appeared to be regarded as magically animated artefacts, akin to living thing (Wolfe, 2004). During the period of Enlightenment, some thinkers began to see automata as models of the human body. They regarded human and animals as automata of a very complex kind. Descartes, influenced by the automata shows in Paris, considered in his *Passions of the Soul* that the body works like an automaton, while the mind (or soul) is

nonmaterial. Nonhuman animals for Descartes are like mechanical automata which cannot reason and do not feel pain. Therefore mechanism of automata became the standard to which Nature and the organism was compared (Schultz & Schultz, 2008, pp.28–34).

In *Principia Mathematica*, Newton's general laws of motion and universal gravitation were used to support the deistic view that God had created the world as a perfect automaton that then required no further interference from Him. Since then, the mechanical models of the Solar System were often taken as a metaphor for the *Clockwork Universe* of Newtonian mechanics.

Newton's clockwork universe, and the conception of the universe based upon rationally understandable laws, became one of the seeds for Enlightenment ideology (Gribbin, 2003, p.241). The clock automata thus became a material account supporting the civil philosophy in later Middle Age Europe (which will be further explored in section 5.3.3). In a sense of media archaeology, the automata are considered to embody mainly two concepts: the image of the *Clockwork Universe*, comparing the movements of celestial bodies with that of clockwork (advocated by Newton and Leibniz); and the image of *Animal Automatism*, comparing the functioning of animal bodies with that of automata (advocated by Descartes and La Mettrie). Implied in these ideas was an idea of harmony and symmetry, a belief of the act of Creation as the work of an inventor-craftsman, and in a deterministic manner of operation. Due to these additional characteristics of automata, rich metaphors evolved from Middle Age Europe onwards. The following sections will explore these metaphors further.

3.3.2 *Metaphorical Artefacts: Clockwork Automata*

As Sawday (2007) contends, in the earlier seventeenth century, machines that could edify, delight, amuse or instill a sense of wonder in the observer were as important as machines

which were made to perform a utilitarian task (Sawday, 2007, p.197). The first group of historical machineries my research finds intriguing are the European clockwork automata, which also had a deep influence on the development of modern technology in the Far East (Macey, 1994, pp.188–192). European clockwork automata in the sixteenth to seventeenth centuries represented not only the products of a unique and sophisticated technology, but also artwork of a high aesthetic standard and an intellectual metaphor for the workings of the universe. This dual elegance in both art and technology makes them Wundermaschinen for cultural historians (Mayr, 1986; Maurice & Mayr, 1980; Sawday, 2007).

The *Carillon Clock with Automata* (1589) (Figure 15) constructed by Isaac Habrecht provides a brilliant example. The clock displays the combined skills of the engraver and the clockmaker. In terms of its technological achievement, it is a timekeeper as well as an accurate astronomical instrument, as *The British Museum* describes:

“The astronomical dial shows the positions of the sun and moon in the zodiac. A calendar provides the date and the Dominical Letter and Saints’ Days. A revolving carousel shows the days of the week, each represented by its ruling planet personified and riding in a chariot.” (‘Carillon clock with automata by Isaac Habrecht’, n.d.)



Figure 15 *Carillon Clock with Automata* (1589), by Isaac Habrecht, The British Museum

The technical skills of this refined piece are not easily visualized. Its principles are revealed only as the device is taken apart. What is, however, immediately apparent is the multiplicity of functions this mechanism can accomplish in a confined space and their precisely calculated form and dimensions, the clarity of design, the symmetry of layout, and the superb engineering skill. The clockmaker needs to have outstanding spatial perception in order to fit his mechanisms with their gear trains into such a restricted working space. At no point does one element interfere with the workings of another. In addition to this, the exterior decoration is as impressive as its mechanism:

“... automata (figures that appear to move under their own power) on the front top operate in time to the striking and the music in an impressive blend of the religious and the secular. The music played at each hour on the carillon is a setting of the Lord’s Prayer written by Martin Luther in 1545.” (‘Carillon clock with automata by Isaac Habrecht’, n.d.)

According to *The British Museum*, this clock is housed in a fine gilt metal case engraved on one side with personified figures of Faith, Hope and Charity, a group of Christian martyred saints (Murphy, 1909). On the other side, there are Wisdom, Justice and Fortitude, a set of cardinal virtues in Platonic and Christian traditions (Cunningham, 1982). Designed in imitation of a great clock in Strasbourg Cathedral, the purpose of these automatic figures was not only for amusement. They were also meant to attract, astonish, and instruct, while suggesting the comparison of the clockmaker with the creator of the universe (Mayr, 1980, p.2). The clock mechanism was to be used “as a symbol of nobility and the disciplined life” (Haber, 1980, p.10), or even, by its regularity, to link “the pattern of human life and the union of the soul with God” (Haber, 1980, p.13).

For some historians, this tendency of emphasizing the automata features of clocks while downplaying their time-telling capabilities culminated in the sixteen and seventeenth

centuries. In fact, early clockwork automata suggested that timekeeping was considered a secondary function:

“One could hardly call it practical or useful: unreliable, imprecise, and overloaded with such extraneous capabilities as astronomical prediction, mechanical music, and automatic theatre, it was a problematic timekeeper. Such shortcomings, however, did not count, for the clock was a wonder of inventiveness, a triumph of craftsmanship, and example of the particular beauty of machinery.” (Maurice & Mayr, 1980, p.vii)

The capabilities of the clock in astronomical and Christian culture suggest that the wonder of the clockwork automata did not simply lie in its time-keeping mechanism or refined craftsmanship but in its additional character. Firstly, as Mayr (1986) notes, one of the additional characteristics of clockwork automata was rooted in “the magic of self-moving machines” (Mayr, 1986, p.21). That included the astonishing capacity to predict and perform celestial movements, play mechanical music and animate life-like figures. This is similar to Friedman’s (1984) description of the clock: “a miraculous contrivance that could imitate the motions of the heavens and of living creatures” (Friedman, 1984, pp.283–284). Secondly, the clock automata, with its rational design and regular running, demonstrated an “orderliness and regularity” (Mayr, 1986, pp.115–116) somewhat in contrast with its historical-political context. As the age of Enlightenment is often considered a period of huge social and economic change, the clock revealed itself as having a character that was essentially divergent to such tendency: an embodiment of an ideal world that was perpetual, disciplined and regular.

As Mayr discussed, clocks in the seventeenth and eighteenth centuries were particularly regarded as a “means of access to the collective mentality” (Mayr, 1986, p.29). For example, in Middle Age Europe the regularity of the clock was often employed by the authoritarians or

the court to illustrate ultimate values. The clock metaphorized an ideal, regular or divine system composed of parts that are connected by direct linkages. As Lewis Mumford (2010) contends, the clock “dis-associated time from human events and helped create the belief in an independent world of mathematically measurable sequences” (Mumford & Winner, 2010, p.15). In other words, the abstract framework of divided time and predictable future became the point of reference for both action and thought. The clock played a central role in the advancement of technology and society during the age of Enlightenment and the clockwork analogy emerged to offer an explanation for the mysterious workings of the cosmos. Living creatures were considered automata and the universe itself was an enormous clockwork machine.

Due to these additional characteristics of clock as technology, rich clock metaphors evolved from Middle Age Europe onwards. The ‘clockwork universe’ was an idea of the universe with its gears governed by the laws of physics, as a mechanical clock and thus predictable (Maurice & Mayr, 1980; Dolnick, 2011). The ‘world-maker and clockmaker analogies’ were understandings of the intelligence of the craftsman and the subtlety of an artistic work that enhanced the understanding and appreciation of the divinity of the world maker. In such a belief, the clock is taken as a representation of the divine and constancy in Christianity (Haber, 1980; Sawday, 2007). There were also analogies between clockwork and physiology. The clock often metaphorized the workings of the human body, or the relationship between body and consciousness (Voskuhl, 2013). In the historical-political context of the 18th centuries, the clock became a reinforcing symbol for an authoritarian political regime (Maurice & Mayr, 1980).

While machines may commonly be described in metaphors, analogies and similes that are beyond their function, the clockwork automata of the sixteenth to seventeenth centuries

exemplified a group of artefacts that should be considered ‘metaphorical’ in a specific way. That is, as machinery, their intricate design aesthetics embodied strong links to the social, political and religious conditions in which they were manufactured. The artefact’s aesthetic criteria (of both mechanism and external craftsmanship) must be considered in close relation to metaphorical imaginings of the ultimate realm (e.g. divine life, authoritarian state and regularity) they are designed to illustrate. From the perspective of a media practitioner, this metaphorical relation between machinery, design and the ultimate realm also provides a potential framework for prototyping contemporary Wundermaschinen.

3.3.3 *Mimetic Motions: Performance Dolls*

Another group of historical artefacts that this research considers wondrous is the mimetic performance dolls, mostly seen in Middle Age European clockwork and mechanical stage shows. The belief in technological progress that characterised clockmaking in the seventeenth century was also reflected in enthusiasm for automata among inventors. Various mechanical puppets were built in an attempt to imitate the natural world, including animal behaviours such as swimming and singing; and human behaviours such as writing, speaking and performing music. These automata were sophisticated inventions using escapement, mechanics and hydraulics, which demanded highly mathematical talents and mechanical ingenuity.

In 1739, Jacques de Vaucanson built the *Defecating Duck* that could quack, swim, flap its wings, peck seeds, and even defecate them (Riskin, 2003). The *Harpsichord Player* made by Pierre and Henri-Louis Jacquet-Droz between 1772-1774, and *The Dulcimer Player* made by cabinetmaker David Roentgen and clockmaker Peter Kinzing in 1785 were both artificial music playing androids that could “move their bodies to communicate affects and sentiments to the audience” (Voskuhl, 2013, p.7). The *Speaking Machine* by Wolfgang von Kempelen

was a manually operated speech synthesizer developed in 1769, which was reported to be capable of speaking complete phrases in French, Italian and English in monotone (Dudley & Tarnoczy, 1950). In the Far East, Japanese *Karakuri* were mechanized puppets made for stage performance between the seventeenth and nineteenth centuries. *Butai Karakuri* were used in theatre; *Zashiki Karakuri* were used in domestic performance; while *Dashi Karakuri* were used in religious festivals to perform re-enactments of traditional myths and legends (Boyle, 2008).

These historical automata attempted to create a sense of wonder in the audience through ‘mimetic motion’, resembling the activity of natural subjects. In the following subsections, I will suggest that mimetic motion should be understood in relation to ‘External Motion Representation’, ‘Physiological Simulation: Internal as External’, and ‘Highly Skilled Activity Mimesis’.

3.3.3.1 *External Motion Representation*

Early mimetic automata intended to represent the behaviour of a natural subject but by no means to reproduce its physiology. For example, the *Threatening Owl and Intimidated Birds* is an example designed by French engineer Isaac de Caus (Figure 16). An owl slowly pivots toward a group of fluttering and chirping birds. When the owl faces the birds, the birds become silent and still. When the owl looks away, the birds chirp up again. The motions are driven by a waterwheel and regulated by a pegged cylinder (labeled X within Figure 16). That is to say, the mechanism is outside of the body of the artificial animal; it is situated externally to the motion of the artificial birds. Another similar example was the artificial swan presented to the Paris Academy of Sciences in 1733 by a mechanic named Maillard. The artificial swan could paddle through the water on a paddle wheel while a set of gears swept its head

slowly from side to side, to make it seem “lifelike in the earthiest sense” (Riskin, 2016, p.135).

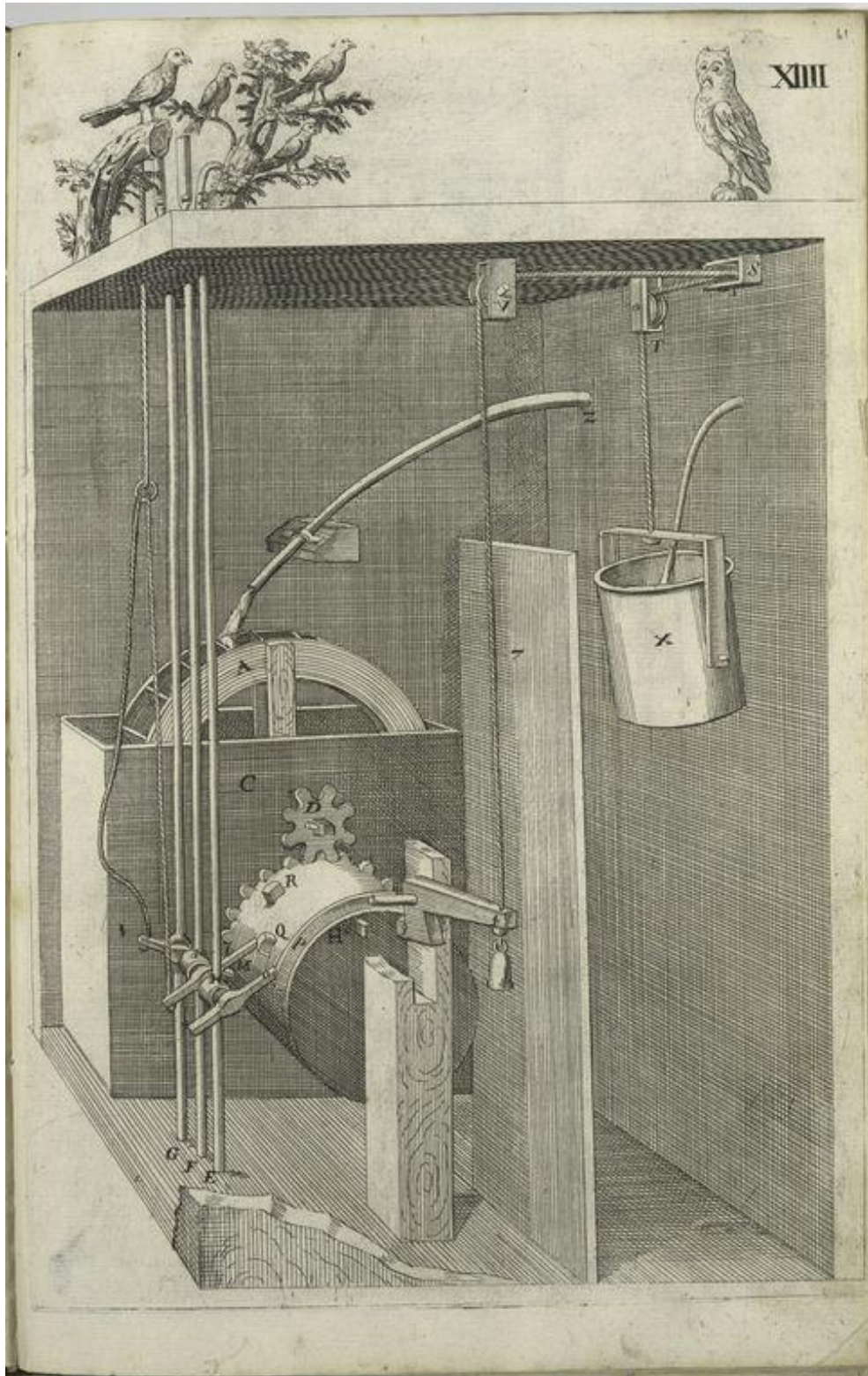


Figure 16 Isaac de Caus's *Threatening Owl and Intimidated Birds Automata*. Image from The New York Public Library Digital Collections

Both the *Threatening Owl and Intimidated Birds* and artificial swan pretended to perform an act that epitomized their animal nature. No matter if the mechanisms were contained inside or outside the puppets, they only intended to represent the behaviour of animals but by no means to reproduce their physiology. I will refer to these as ‘External Motion Representation’ artefacts. Such artefacts embodied a question people were eager to think about in the eighteenth century: whether natural phenomena worked in essentially the same way as artificial ones. They were created not to perform utilitarian tasks but to arouse curiosity and discourse.

3.3.3.2 *Physiological Simulation: Internal as well as External*

By the late eighteenth century, automata were imitative internally as well as externally, in their mechanism as well as in appearance. The automata makers tried hard not only to mimic the outward appearances of life, but also to follow as closely as possible the mechanisms that created these appearances. For example, examination of the *Harpsichord Player* built by Jaquet-Droz in 1774 showed that the hands were probably designed with the help of the village surgeon, their skeletal structures modeled on real human hands (Figure 17). It was such mechanical anatomy that allowed *The Harpsichord Player* to perform more sensitive gestures.

As Voskuhl (2013) suggests, *The Harpsichord Player* indicated a strong intent to make the automaton perform subtle and graceful body motions in addition to simply playing music. The automata’s bodily motions corresponded to eighteenth century performance techniques, as musicians at the time were expected to move their bodies while playing music to communicate affects and sentiments to the audience. Voskuhl argues that this act of

“cultivating sentiments” (Voskuhl, 2013, p.7) was not only a feature of making and listening to music at the time, it was also part of a larger social movement in the European Enlightenment and was practiced in the reading and writing of literature, in the sciences and natural philosophy, in letter-writing and friendship, and in travel culture. The sentiments performed by automata were taken as a means to form new types of social interaction and used as the basis for a new, more equal and just social order: civil society (Voskuhl, 2013, p.7). In addition, as Riskin (2003, p.604) suggests, these early explorations of ‘physiological simulation’ in automata had also allowed for an infinity of possible mechanisms underlying nature’s visible behaviours, and further gave way to a growing confidence whereby experiment in machinery could somehow reveal nature’s subtle design.



Figure 17 The simulative hand of the *Harpsichord Player* (called *Lamusicienne*) made by Pierre and Henri-Louis Jaquet-Droz, La Chaux-de-Fonds, 1772–1774

3.3.3.3 *Highly Skilled Activity Mimesis*

In contrast to the preceding two types of mechanical dolls, there were also mimetic automata that performed simulations that were purely functional, with no attempt to reproduce the outward appearance of the natural model. Inventor Wolfgang von Kempelen's experiments on *Speaking Machine* beginning in 1769 was one example (Dudley & Tarnoczy, 1950) and Vaucanson's *Automatic Loom* provided another. The *Speaking Machine* by Kempelen was a manually operated human speech synthesizer containing a functional model of the human vocal tract. Kempelen conducted intensive research on the vocal tract in relation to spoken languages, in which the behavior of each crucial physiological element of speech production was scrutinized and replicated acoustically and mechanically. Similarly, the *Automatic Loom* made by Joseph Marie Jacquard, which was first demonstrated in 1801, did not reproduce the motions of a human weaver in the way that the *Harpsichord Player* enacted those of a human pianist. On the other hand, it took over a function that had hitherto been not only human but also highly skilled: the weaving of patterned fabrics.

Another remarkable example of these highly skilled activities mimicked by automata was the *All-Writing Miraculous Machine* (Figure 18) made by Friedrich von Knaus in 1760. The machine was presented to Emperor Francis I and the Court on the 4th of October 1760 at which time it wrote a paragraph³ in French. According to Bedini (1964, p.39), this machine was able to write any phrase composed in advance, and it could write to dictation by means of a hand-operated control on the letter keyboard. A very detailed description of this apparatus' craftsmanship can be found in the website of The Museum of Technology in Vienna:

³ "Dear Sir, do me the honour of listening to me and to what I am writing for you. The world thought that I would never be perfected by my maker, he was even so persecuted, that it was possible: but now, he put me into such a state that I write all languages, despite all his envious people, and I am truly, Dear Lord, the most loyal secretary."

“A brass figurine holding a quill sits atop a globe. Inside the globe is a pin drum on which a sequence of letters can be set by hand. Driven by a spring mechanism the automaton is capable of writing up to 68 stored letters by itself. The control mechanism also ensures that the writing support advances after each written letter and after every completed line. Curved discs acting as templates make sure that the mechanical quill executes the correct stroke for each letter.” (‘All-writing miraculous machine Writing apparatus: Friedrich von Knaus, Vienna, 1760’, n.d.)



Figure 18 *All-Writing Miraculous Machine* (Allesschreibende Wundermaschine) by Friedrich von Knaus in 1760

While this machine was pioneering engineering in 1760, the decoration also showed a high artistic quality of craftsmanship including sophisticated decorative figures, a goddess, globe and cloud all set upon a fine-carved wooden stand. These metaphorical figures made reference to contemporary belief systems and triggered the viewers' imagination. As a miracle-working machine in the eighteenth century, this automaton could perform a highly skilled activity that transcended many human-hand writing skills at the time. The design of such mimetic motion machinery thus represented a pursuit of highly skilled activity or real intelligence that aims to surpass human abilities.

3.3.3.4 What is the Contemporary Mimetic Motion?

The three historical tendencies of mimetic motion, from the imitation of external appearance (section 3.3.3.1), the simulation of the physiological (section 3.3.3.2), to the performance of sophisticated highly skilled activities (section 3.3.3.3), showed that these automata demonstrated observable qualities related to the achievement of sensitivity of living through engineering. They suggest 'mimetic motion' as a critical techno-historical characteristic of canonical Wundermaschinen. This review urged my research to ask: what is the contemporary mimetic motion of artefacts that can intrigue the viewers by utilizing technology? The critical significance of this question is clear when we recall Riskin's (2003) analysis: the canonical mimetic automata in Middle Age Europe were:

“a continual redrawing of the boundary between human and machine and redefinition of the essence of life and intelligence, as certain human occupations came to seem less human and others more human, according to what machines could and could not do.” (Riskin, 2003, p.633)

In this sense, my research's interest in contemporary mimetic motion can be considered a creative inquiry that aims to imply potential meanings for the essence of human life and intelligence. Such exploration of mimetic motion as an inquiry into human intelligence is thus an experimental aspect for contemporary Wundermaschine practice.

3.3.4 *Mechanisms of Illusion and Trickery: Magical Machines*

Unsurprisingly, it is easy to find accounts of magic-performing automata in history. These magical automata were demonstrated in a performance-like setting to strike awe and wonder into the spectators by means of 'deceit'. By 'deceit', I mean these automata demonstrated spectacles of wonder by hiding the real mechanisms, or creating an illusion for the audience that was far more astonishing than its real working principle. These kinds of Wundermaschinen were constantly built to create a sense of awe, to stimulate curiosity and to provoke the re-examination of previously established understanding in the observers.

In Frances Yates's academic works, we see the important role magic played in early modern science and philosophy (Yates, 1964). Yates suggests that various forms of magic thinking and practice were foundations in the Renaissance understanding of the natural world. She suggests that occultism, esotericism, and Hermeticism all played important roles in the development of Renaissance culture and the scientific revolution. For example, between 1300 and 1600 A.D., the Renaissance Hermetic movement in Western Europe encouraged the study of some of the genuine applied sciences, including mechanics, an area that Tommaso Campanella was later to term as "real artificial magic" (French, 1972, p.109). Early forms of magic lanterns developed by Giovanni Fontana in the fifteenth century were used to project images of demons (Pfragner, 1974, pp.9–21). Occultist and scientist John Dee, branded as the great conjuror for his angel-summoning magic, constructed *mechanical Scarabaeus* that he demonstrated at Trinity College, Cambridge in 1547 (Hogg, 1951, p.160).

In the eighteenth century, this notion persisted while many deceit automata were constructed to create illusions. Vaucanson's *Defecating Duck* (1739), which is considered by scholars to be the earliest example of "biorobotics" (Sharkey & Sharkey, 2006, p.11), had a hidden mechanism that imitated the duck's digestive system. Little pellets eaten by the duck were seen passing into the stomach, being digested, moving into the intestines and coming out of the anus as little pellets. However, after Vaucanson's death, it was discovered that the little pellets had actually been inserted into the duck's anus and had no connection to the rest of the digestive system. Another celebrated automaton, *The Turk*, or *the Automaton Chess Player* (1770)(Figure 19) constructed by Wolfgang von Kempelen, was a mechanical deceit that allowed a human chess master hiding inside to operate the machine. The mechanism appeared to be able to play a strong game of chess against a human opponent. From 1770 until its destruction by fire in 1854, various owners exhibited this deceitful chess-playing mechanism though it was exposed in the early 1820s as an elaborate hoax (Schaffer, 1999, pp.154–163).

With an intention to "top the illusion" (Jay, 2000), *The Turk* consisted of a life-sized model of a human head and torso dressed in Turkish robes and a turban which implied an Oriental sorcerer. The front of the cabinet consisted of three doors that could be opened to reveal a red and white ivory chess set, as well as mechanisms similar to clockwork. The interior of the machine was very complicated and designed to mislead those who observe it. A sliding seat was installed in the cabinet allowing the hidden operator inside to slide from place to place and thus evade observation as the presenter opened various doors. According to Standage (2002) the design allowed the presenter of the machine to open every available door to the public, and yet maintain its illusion.

Similar to *The Turk*, there were also power machines that were un-functional, but purposely demonstrated for trickery. These machines were often presented as models, proposals, design diagrams or blueprints, based on un-tested or pseudo-scientific principles. One intriguing example was the strange invention of nineteenth century American mechanic John Keely.

In 1874, Keely proposed a “hydro-pneumatic-pulsating-vacu-engine” (Figure 20), later called *The Keely Motor*. Keely claimed his machine was able to generate an intensive power that was described as a “vaporic” or “etheric” force (Moore, 1996, pp.61, 157–158, 275) based on “vibratory sympathy” (Moore, 1996, pp.130, 145–147, 173, 225). Keely claimed that this

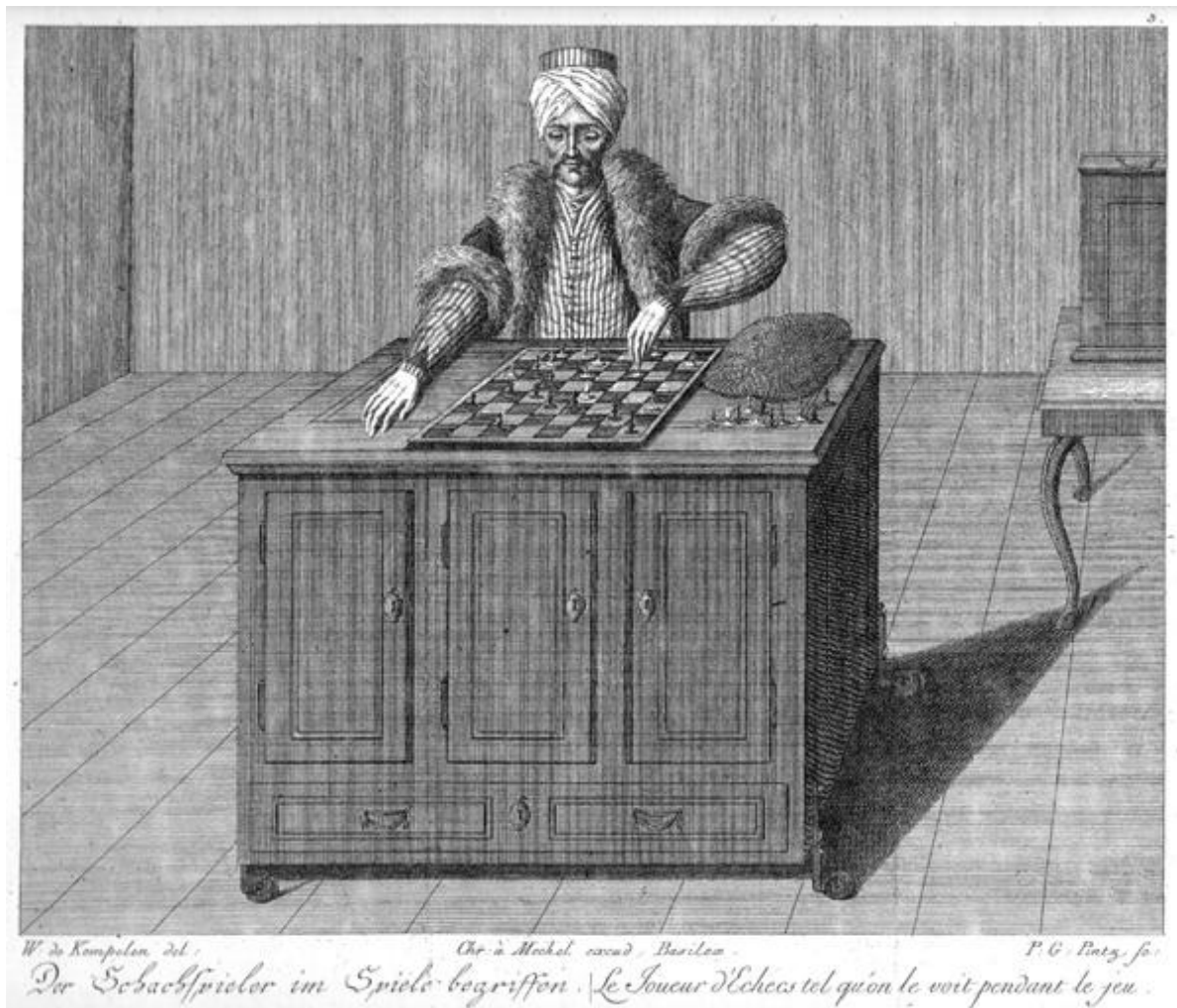


Figure 19 An engraving of *The Turk* from Karl Gottlieb von Windisch's 1784 book *Inanimate Reason*

etheric force could be produced from pure water and air. The motor/generator was constructed based on Keely's etheric theories, according to a report of *New York Times* in 7 June 1885:

“There is a certain magnetic effect about it that causes it to adhere by vibratory rotation to different forms of matter – that is the molecular, atomic, etheric, and ether-etheric. The impulse is given by metallic impulses, the rotary power that is formed by etheric vibration – that is the force that holds it in position.” (‘Keely’s Red Letter Day’, 1885)

The Keely Motor was demonstrated many times in America between 1874 and 1885, convincing the general public that the water had been disintegrated and a mysterious vapor

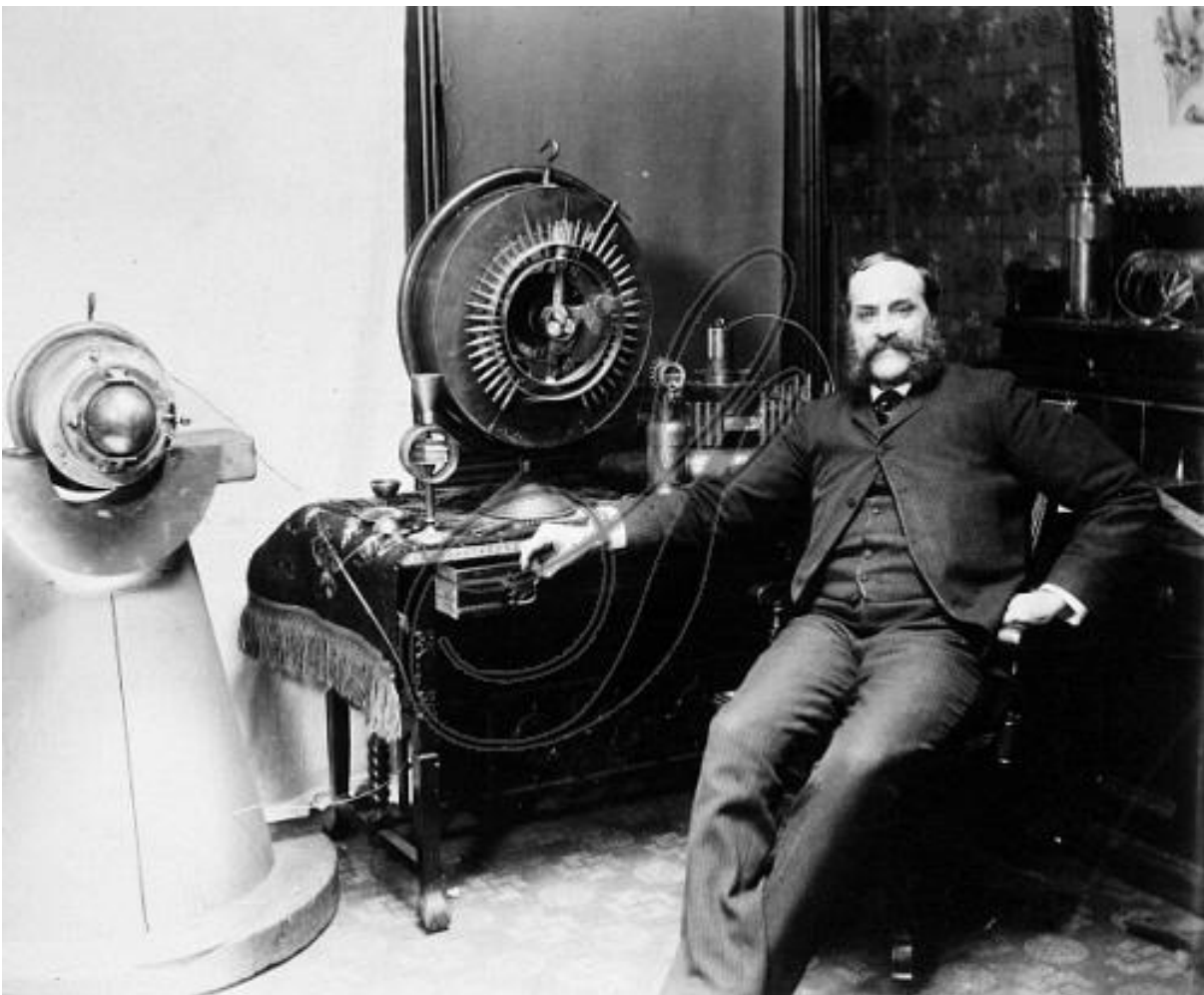


Figure 20 John Keely and his “hydro-pneumatic-pulsating-vacu-engine” in 1895

had been liberated in the generator, capable of powering machinery. According to a report of *New York Times*, Friday, 9 July 1875:

“The apparatus by which this power is made is termed a “generator” or “multiplier”, and the vapor is then passed into a “receiver,” and from thence to the cylinder box of the engine, where it drives the pistons and sets the engine in motion. The generator is about three feet high, made of Austrian gun metal, in one solid piece, and will hold about ten or twelve gallons of water. It is four or five inches thick, and made to stand the very heavy pressure of 20,000 to 20,000 pounds of vapor to the square inch.” (‘The Keely Motor’, 1875)

However, many facts, including a published article detailing an investigation of Keely’s workshop on 19 January 1899 after his death (‘Keely’s Secret Disclosed: Scientists Examine His Laboratory and Discover Hidden Tubes in Proof of His Deception’, 1899), proved *The Keely Motor* to have been a deception, its alleged mysterious forces to have been the result of trickery, and Keely, a fraud and a conman.

In the history of technology, *The Turk* and *The Keely Motor* are often described as “Wundermaschinen” or “trickery machines” (Schmeh, 2010) by which a sense of awe was aroused by means of deceit. Interestingly, both von Kempelen and Keely’s goal was to create a false belief in technology itself rather than in the supernatural. In chess-playing computers from *Deep Blue* onwards, we see what *The Turk* foresaw. *The Keely Motor*’s dream to generate intensive power through a compact device was also realized in nuclear reactors. That is to say, all these machineries of deceit inform us of the inseparable connection between technology and illusion. We should not exclude magic from the development of modern technology, neither can we draw a clear boundary between illusion making and engineering. And it is such an inseparable connection that critically characterized the canonical Wundermaschinen.

Consequently, this review of mechanisms of illusion and trickery identifies close similarities between the demonstration of Wundermaschinen and stage magic. Through hiding the mechanism or exaggerating the presentation, the artefact designer may create a wondrous illusion that possesses the viewer. This notion of creating illusion and trickery also has been reflected in my preceding project *Spiritual Exposure V.1 and V.2* (in section 2.3), since an information visualisation technique was utilized, and deliberately hidden, to create images of spirits. This notion of illusion and trickery re-affirms the exposition of ‘overlapping identity between an engineer, psychic and magician’ (section 2.3.6). Accordingly, a form of magic presentation has been included in the design and exhibition of later projects.

3.4 Creative Machine Prototyping in the Emerging Maker-culture

3.4.1 *Computer-assisted Fabrication: Accurate, Individualized and Nomadic*

Computer-assisted fabrication refers to a process that joins design with construction or production through the use of computer modelling or additive/subtractive manufacturing tools (i.e. 3D printers or laser cutters). It allows makers to produce material through a computational process (Gershenfeld, 2005; Mota, 2011). In my research, the computer-assisted fabrication tools are critical in both how the concept of a Wundermaschine will be materialized, and how this practice is linked to a wider socio-cultural background of personalized artefact prototyping in emerging maker-culture.

Scholars like Mota (2011) often claim that we have been witnessing a stage of the “democratizing of manufacturing” (Tanenbaum, Williams, Desjardins & Tanenbaum, 2013; Mota, 2011), a trend that is guided by the development of fabrication technologies. This trend advocates practical skill learning and a technology-based extension of DIY culture. Under the banners of “personal fabrication” and “desktop manufacturing” (Brockman, 2015; Mota, 2011), the previously exclusive domain of manufacture has become accessible at a personal

scale, and the once costly and inaccessible domain of single-item fabrication is opening out to wider audiences/users with the advances in rapid prototyping (RP) fabricators. The decreasing cost of these fabricators, such as laser cutters, CNC mills and 3D printers, has made them more accessible for creative media labs and led to a growing desire amongst individuals to shape and personalize the technological artefacts they use. This makes possible not only the production of personal material objects but also the manufacture and assembly of components for more complex products, such as the machines themselves. The accuracy of these contemporary fabrication tools allows the intensive creation of complicated artefacts that would have been costly and labour intensive a decade before.

Scholars like Mota (2011) also claim that computer-assisted fabrication tools (especially 3D printers) provide the advantage of being able to make small amounts of individualized customized parts, which benefit the creative individual by allowing them to create more sophisticated artefacts that can perform dynamic tasks, or create artefacts that are intended to be distinct from everyday electronic products. Mota (2011) suggests that through computer-assisted fabrication, individuals can go against standardized, regularized and planned-obsolescent electronic goods and embrace an artisan spirit of assemblage or collage. This maker-culture not only makes it possible to manufacture a single artefact which is the “fabrication for a market of one person”, as Neil A. Gershenfeld claims in an interview by (Brockman, 2015), but also creates new possibilities for creative output. This culture encourages individuals to create subtle artefacts that deal with localized, personalized tasks. For example, *The Bacon Alarm Clock* (Llopez, 2005)(Figure 21), *The Plant Whisperer* (Jeff-o, 2011) and *The Arduino Chicken Incubator* (DHTArduinoNerd, 2014) on maker website *Instructables* exemplify how machines today can be creatively prototyped for a specific need and private desire.

This transformation of means of machine prototyping, focusing on swiftly creating at home and sharing worldwide, stresses a cut-and-paste approach to standardized hobbyist technologies, and encourages cookbook re-use of models and blueprints published on the internet and in maker-oriented publications (MacMillan, 2012). Some claim that this is a move toward personalization and re-appropriation of manufacturing, and is a “revival of the pre-industrial era of artisan production” (Mota, 2011, p.286). Other research discusses how this maker-culture both implicates and impacts professional designers (Tanenbaum et al., 2013, p.2603) in the way that it is joined with the rise of online communities of “expert amateurs” (Bardzell, 2007; Kuznetsov & Paulos, 2010; Pace, Toombs, Gross, Pattin, Bardzell & Bardzell, 2013); investigations into computer-assisted fabrication methods and their connections to technological innovations (Mota, 2011); and creative reuse of everyday objects (Maestri & Wakkary, 2011).

As a practitioner/researcher utilizing maker tools, I acknowledge that there is not enough focus on how emerging computer-assisted fabrication relates to the aesthetics of



Figure 21 *The Bacon Alarm Clock* by Llopez, 2005. Image from: *Instructables*

self-expression, individual desires, beliefs, or to exemplify how it specifically “unifies playfulness, utility and expressiveness” in creative individuals (Tanenbaum et al., 2013, p.2603). This inquiry into such individualized making-thinking can be related to Zygmunt Bauman’s (2001) concept of “liquid modernity” in which he describes a society that is more atomized, a society of “emancipation and individuality” (Bauman, 2001). Bauman’s arguments on liquid modernity emphasize the increasing feelings of uncertainty and the “privatization of ambivalence” (Bauman, 2013) that individuals experience. That is, the attainment of clarity of purpose and meaning is an individual task and personal responsibility. He sees the contemporary world as a kind of a continuation of modernity, where an individual can shift from one social position to another in a fluid manner:

“...it is such a fluid form of assembly which fits their view of the surrounding world as multiple, complex, and fast-moving, and therefore ambiguous, fuzzy and plastic, uncertain, paradoxical, even chaotic”. (Bauman, 2001, p.154)

For Bauman, nomadism becomes a general trait of the liquid modern subject as one flows through his own life like a nomad, shifting values, places, spouses, and sometimes more, such as sexual or political orientation, in the process excluding himself from traditional networks of support. In the spirit of Bauman, what this research is particularly interested in is: What are the implications of a machine prototype that refuses to accept established knowledge and recognizes the wisdom of the lessons of accumulated experience for creative individuals today? In other words, this research explores computer-assisted fabrication of machines of wonder, not to advocate the over-generalized notion of “new industrial revolution” (Mota, 2011; Anderson, 2012, 2010), but to invent, to question assumptions, and to embody personal, private knowledge in machine prototyping with maker tools.

In addition, this research echoes back to Buchanan's (1992) "wicked problems" in design thinking. That is, Buchanan acknowledges that the actual sequence of design thinking and decision-making is not a simple linear process, and the problems addressed by designers do not yield to any linear analysis and synthesis. There is a fundamental indeterminacy (Buchanan, 1992, pp.15–16), impossibility (Buchanan, 1992, pp.20–21) and particularity (Buchanan, 1992, p.17) in all design questions. A notion of 'Wundermaschinen as wicked artefacts' suggests the complex inquiries addressed by designing a Wundermaschine, to which no correct design solutions exist a priori and for which formulating the situation is integral to addressing the inquiries.

To put it in a nutshell, this research on creating a Wundermaschine that adopts computer-assisted fabrication tools embodies a particular desire to create metaphorical, mimetic motional and illusionary artefacts (as contended in section 3.3). Multiple techniques of computer-assisted fabrication have been adopted as a means of producing single-item artefacts that are distinct from mass-produced ones, in terms of the final output as well as the prototyping process. Such tools are not only beneficial to this research's need for fast reflective-experimenting, they demonstrate how this research is corresponding to, and mutually informed by, the 'accuracy, individualized and nomadic' features of contemporary maker-culture.

3.4.2 ***Reflections through Open Source Making: Homogenisation of Novelty***

The Internet augments new means and communities of artefact making. Open source is a development model that promotes universal access via a free license to a product's design or blueprint, and universal redistribution of that design or blueprint, including subsequent improvements to it by any others. As the Internet connected engineers and their computers with each other they developed peer-to-peer working methods to learn, create and share

knowledge and code with each other across social and geographical distances. Open source largely influences how an artefact can be developed, co-opted and distributed.

Many scholars have claimed that the open source way of making “empower[s] people to experiment” (Weber, 2004, p.234), enables a “shared language between makers” (Frost, 2012), and contributes to “a system of sustainable value creation and a set of governance mechanisms” (Weber, 2004, p.234). For some, open source not only urges the creative practice of appropriation and free sharing of found and created content, which includes hardware blueprints, computer source code or developmental models, but also promotes universal access to them for making improvements or enhancing diversity. Often coinciding with the emerging idea of “prototype over product” (Frost, 2012) and “peer-to-peer learning networks” (Catlow &Garrett, 2012), open source is concerned with increasing the “potential sociality” (Catlow &Garrett, 2012) of the creative artefact and its participants and audiences.

As a practitioner/researcher, the most intriguing aspect of open source is how it encourages us to structure information, either in computer language or accounts of hands-on making, so it can be reused and recombined with other pieces of information. This research has benefited from open source making in several ways. For example, the technical support available from open source software and online communities makes it effective for prototyping mono-machines – it helps this research experiment with designs and blueprints more effectively, mostly with a cut-and-paste approach and the re-use of programming code and libraries. Secondly, open source cultivates creativity by lowering the barrier to the creation and modification of physical artefacts, and facilitates a collaborative peer-to-peer learning system. This means faster concept modelling, debugging and easier communication and technical solution-finding during project development. For example, in the practice of *Sensing Energies* (described in section 2.2), open source facilitated my collaboration with computer

scientists. My aesthetic aim of creating an information visualisation that had visual complexity was developed and tested through coding in *Processing*, before applying an open source library that scrapes sensor-data from the King's Gate Building in Newcastle University with the help of computer scientists.

However, during the course of study, I have also found a contradictory element while working with open source tools. That is, how can a creative individual make a unique artefact in a community that advocates the free distribution and re-using of prototyping knowledge? As technical details and prototyping means are published online for everyone, it is not unusual to find overlapping similarities among projects built within the same open source environment. For example, most *Arduino* projects in the *Instructables* platform now seem to share a simple logic of input-output system, such as in *Arduino XMAS Hitcounter* (Weber, 2008), *Arduino Bike Speedometer* (Amandaghassaei, 2013a) and *Arduino Vocal Effects Box* (Amandaghassaei, 2013b)(Figure 22). This suggests that open source tools may not really encourage individuals to explore private knowledge or desires in technological practice (as many scholars claim in section 3.4.1), but only make creative projects even more similar. In contrast to the optimism of the advocates of digital fabrication reviewed earlier, this research proposes that there is a 'homogenisation of novelty' in contemporary maker-culture. This homogenisation of novelty that underlies open source tools could raise critical questions: How can practitioners create novel artefacts under the inevitable influence of the similar logic and knowledge of open source prototyping? How can they respond to the phenomenon of open source making by engaging both its advantages and contradictions?

3.4.3 *Proposing Three Experimental Aspects in Digital Fabrication*

In a conscious attempt to go beyond the homogeneity, the machines prototyped in my research applying means of computer-assisted fabrication and open source making, are proposed to explore three specialized aspects: ‘Machine of Specific Sensuousness’, ‘Occurrent Awareness of Life’ and ‘Information-oriented Experience’. These three aspects originated from reflections on early projects (summarized in section 2.4) and the review of contemporary maker-culture (discussed in section 3.4.1 and 3.4.2).

3.4.3.1 *Machine of Specific Sensuousness*

As a practitioner, prototyping with computer-assisted fabrication particularly enables this research to create machines of specific sensuousness. As I have noted, the accuracy and efficiency of computer software and fabricators make it more possible to assemble machines for a particular function. This suggests that a machine prototype now can perform an intimate engagement with a particular object, absorbing its specific appearance, texture, and characteristics to generate a sequence of events and actions for the viewers’ experiential and imaginative engagement.



Figure 22 *Arduino Vocal Effects Box at Instructables*

This thread of making machine of specific sensuousness reminds us that experiences in digital technology are particular. They relate to a particular person in a particular situation at a particular time. The machine or event is thus to be experienced in the here-and-now through the bodily presence of each viewing subject. The machine can form intimate relationship with an object, as well as guiding the viewer's experiential and imaginative engagement.

In this sense, the object the machine can interact with plays a critical role in the viewers' engagement of the wonder I create. This means the artefact is not only made to perform particular function, but will generate a sequence of events, experiences and actions through that particularity. This experimental sense of a machine of specific sensuousness will be mainly explored through two pieces: *Experiential Converter* (which will be described in section 4.6), a 'colour-wheel-reading correspondence machine' designed for a music-box-like setting that encourages viewers to interact around it, and *Botanical Universe* (which will be described in section 5.6), a 'plant-empathetic clock' for an outdoor garden that aims to envision a wondrous, hybrid image of a possible future.

3.4.3.2 *Occurrent Awareness of Life*

Adopting terminologies from recent discussions of the Internet of Things (IoT), the combination of the Internet and contemporary technologies such as "near-field communications, real-time localization, and embedded sensors" (Kortuem, Kawsar, Fitton & Sundramoorthy, 2010, p.30) enables the transformation of everyday objects into smart objects that can understand and react to their environment. As Kortuem et al. (2010) suggest, the contemporary design for smart objects increases the awareness and interactivity of our surrounding objects. Technology has become an extension of one's awareness of life, so an artefact can play a critical role in the network of others.

“...smart objects carry chunks of application logic that let them make sense of their local situation and interact with human users. They sense, log, and interpret what’s occurring within themselves and the world, act on their own, intercommunicate with each other, and exchange information with people.”
(Kortuem et al., 2010, p.30)

My research goes beyond the applications typically discussed in IoT to explore the potential for wonder. This ability suggests the artefact somehow embodies the sensitivities of organic life, such as reaction and awareness, and has the ability to influence human activities. In contrast with studies in the field of robotic science, my research understands this emerging characteristic of artefacts’ ‘awareness of life’ in an aesthetic approach. It concerns how this specific characteristic of artefacts (that this research aims to produce) can engender wondrous and occurrent events.

As one of the abilities of computer-assisted fabricated artefacts, this occurrent awareness of life is speculated to show multiple relativities between information, participants and events as they occur, allowing the artefact to observe, react dynamically, and create novelty based on the recipient and space. The practical insight of this experimental aspect will be illustrated through *Samsare Eye*’s exploration of real-time body motion correspondence (which will be explained in section 4.2) and *Experiential Converter*’s attempt to reveal the concurrent sound and motion of every colour detected (which will be explained in section 4.6).

3.4.3.3 *Information-oriented Experience*

Using computer-assisted fabrication and open source making also enables this research to study ‘information-oriented experience’. What I mean by ‘information-oriented’ can be illustrated by the experimental projects described in Chapter 2. In *Sensing Energies* (section 2.2), the information was the environmental conditions: temperature, light, audio, PIR (passive infrared sensor), battery usage, and humidity, that were captured by the forty-six sensors in the

2nd floor, King's Gate Building in Newcastle University. These dense real-time data streams were visualized in a 3D animation, which created understanding of another physical space. In *Spirit Exposure* (section 2.3), the information was the motion variation pattern captured by the laptop camera in the public space. The information was collected on site and helped create an esoteric experience away from everyday experience. These two projects affirmed that 'information-oriented' was an emerging quality of computer-assisted fabricated artefacts and should be further explored in researching machines of wonder. In particular, the projects *Samsare Eye* (section 4.2) and *Botanical Universe* (section 5.6) concern the richness of experience that sensor technology can bring to an audience. Both projects apply an information-oriented design in their mechanism and exhibition setting, and particularly aim to see how the technical processing of information can engender an experience of wonder in the viewer/participant.

In summary, through contextual review and reflection on early projects, this research proposes Machine of Specific Sensuousness, Occurrent Awareness of Life and Information-oriented Experience as three experimental aspects for a practice toward Wundermaschine. These three aspects will be merged into the design aesthetics, material choices and exhibition settings of later projects.

3.5 From Critical Analysis of Canonical Wundermaschinen to Speculations of Contemporary Wundermaschinen

In section 3.3, it became apparent that there are overlapping similarities and tendencies among historical machines but that none of the aspects mentioned are common to absolutely all machines – although they all resemble each other in some way. Therefore, the consistent meaning of Wundermaschine is more a network of automata with a "family resemblance", as considered by Ludwig Wittgenstein (Wittgenstein, 1953, 1998; Griffin, 1992). That is to say,

the German terminology Wundermaschine (single form) and Wundermaschinen (plural form) is applied to a group of automata/machineries which may be thought to be connected by one essential common feature (i.e. some specific quality) but are in fact connected by a series of overlapping similarities, where no one feature is common to all.

Wittgenstein's family resemblance concept also reminds us that there is no reason to look, as we have done traditionally, for one essential core in which the meaning of a word is located and which is common to all uses of that word. Wittgenstein suggests that we should, instead, travel with the word's uses through a "complicated network of similarities overlapping and criss-crossing" (Hanfling, 1989, p.64). In my research, Wittgenstein's (1953) notion of "criss-crossing" found its commonality with Ingold's (2013) concept of making as "meshwork weaving". That is, no categorical separation should stop a practice-based research from making creative works.

As part of the criss-crossing, we may experiment with how canonical Wundermaschinen can crisscross with contemporary technology. We may also experiment with how the three canonical features of Wundermaschinen (analysed in section 3.3) could be juxtaposed with the three experimental aspects of contemporary creative machine prototyping (analysed in section 3.4). Adopting Ingold's notion of a "maker's foresight" (Ingold, 2013, pp.66, 69–72) wherein experienced practitioners plan ahead in response to materials with "the ability to form a plan or representation in mind in advance of its material realisation" (Ingold, 2013, p.66), the following seven design aspects were speculated for further experiments into contemporary Wundermaschinen:

3.5.1 *Rarity and Refined Labour*

As we can see in preceding discussion, the canonical Wundermaschinen suggested that viewers needed to travel far to see the artefacts and they were only demonstrated in venues that were convenient for maintenance. The Wundermaschinen were thus artefacts of rarity: they were highly finished and impossible to duplicate or mass-produce. Such rarity and refined labour informed my media projects to particularly experiment with the potential of introducing various forms of intensive labour (e.g. computer coding, artefact design, sound design and novel assemblage of materials) into work and producing highly finished artefacts.

3.5.2 *Information-oriented Visual Complexity*

As section 3.3 shows, the canonical Wundermaschinen were intricately decorated or handcrafted and each represents the specific visual-aesthetics of a particular era or cultural background. Therefore, I should explore how such visual complexity could be achieved through computational measures. As I have contended in section 3.4.3.3, ‘information-oriented’ is an emerging experiential quality for computer-assisted fabricated artefacts. As I have also explored through *Sensing Energies* (annotated in section 2.2), a dense, vivid and complex visualisation of environmental information can be created without information reduction or sampling. How such information-oriented visual complexity can be further explored through more physical means will be described in later projects.

3.5.3 *Performance-like Setting for Specific Sensuousness*

As the literature review shows, the canonical Wundermaschinen were presented performatively – in a special setting with a specific purpose. In terms of clock automata, the mechanical performance during the hourly strike implied not only highlighting and drawing viewer attention, but also embodied metaphors of social order and divine life (as discussed in section 3.3.2). In section 3.4.3, I have also proposed ‘machine of specific sensuousness’ as

one critical experimental aspect of the computer-assisted fabrication. This research thus should explore through practice how a machine could perform an intimate engagement with a particular object and generate a sequence of events and actions for the viewers' experiential and imaginative engagement.

3.5.4 *Embracing Knowledge across Disciplines*

The construction of canonical Wundermaschinen demanded professional knowledge across disciplines. For example, the European android automata not only evolved out of a set of precisely calibrated mathematical procedures, but have been thought of as products of a “marriage of philosophy and craftsmanship” (Voskuhl, 2013, p.16), mechanisms of “real artificial magic” (Yates, 1964, p.149), or a poetic fabrication of “speaking pictures” (Sawday, 2007, p.199). They were constructed with natural philosophical, aesthetic, and mechanical knowledge. This trans-disciplinary character encouraged my projects to experiment courageously with how the computational could engage, or envision, potential connections between disciplines.

3.5.5 *Assembling Multiple Epochal Technologies*

This research recognized the potential of assembling multiple ‘epochal’ technologies through making contemporary Wundermaschine. It suggests the ability of technology to multilaterally transform the relations/characters of other technologies. This definition of ‘epochal’ was largely inspired by Kittler’s “discourse network”, as Kittler defined it: “the network of technologies and institutions that allow a given culture to select, store, and process relevant data” (Kittler, 1985, p.369). In this view, the clockwork and the computational were particularly considered epochal in human history. How, if possible, could these two be juxtaposed through making? Could a contemporary exploration of Wundermaschine alternatively redefine their ‘epochalness’? This notion will be explored in later projects.

3.5.6 *Machinery of Curiosity through Occurrent Processing*

As Voskuhl (2013) argues, the canonical Wundermaschinen de-stabilized the spectators' sense of the boundary between human and machine, and by extension, evoked a broad range of concerns relating to the epistemological, social and economic changes in the age of their construction. The wonder of these automata should include their capabilities for creating a conceptual space for exploration. That is to say, the Wundermaschinen responded to curiosity and created curiosity – they were machineries for engaging and provoking knowledge (of Nature, Divinity and civil philosophy as I explored in section 3.3) and that made them a 'machinery of curiosity'. For example, the design of the *Harpsichord Player* responded to the curiosity of how the automaton's body motion could correspond to eighteenth-century performance techniques. Once performed, it provoked knowledge not only about mechanical techniques, but also furthered understanding of the "social movement of cultivating sentiments" (Voskuhl, 2013, p.7) in the European Enlightenment, and how sentiments were used as means to form new social interaction toward an ideal civil society.

This notion of 'machinery of curiosity' will be explored further through practice. This is because the contemporary artefacts designed with computer-assisted material and tools possess the ability to process events as they occur, allowing the mechanism to observe, react dynamically, and have curious effects on the recipient and space (as contended in section 3.4.3.2). Such an ability to create the sensitivity of organic lives could have significant potential in influencing human activities.

3.5.7 *Object of Philosophical Argument*

In section 3.3, the canonical Wundermaschinen often embodied specific epistemological positions and were therefore often applied by scholars as arguments. For example, the

‘mimetic motion dolls’ (section 3.3.3) simulate mechanically the human/animal body and thus became an argument for physiology and neurology. Thomas Huxley developed in 1874 a theory that humans are conscious automata (Huxley, 1992), by which consciousness is epiphenomenal, a by-product of neural process. Descartes also relied on metaphors and models of the clock and the automaton as he developed his rationalist epistemology and dualistic conception of matter (Descartes, 2008, p.58) (Mayr, 1986, pp.82–88). The work of Leibniz and Wolff also relied on clock metaphors for the relationship between knowledge and divine revelation (Weissman, 1996).

From a practitioner’s perspective, such examples show how artefacts could be demonstrated as an ideal material form of a statement. The canonical Wundermaschinen demonstrate an appropriate media form, expression or framework of prototyping for the artist/designer to state a critical argument, especially towards a more fundamental philosophical concern, or a specific worldview. This feature of canonical Wundermaschinen makes them similar to how contemporary design objects work in ‘speculative design’ (Dunne & Raby, 2013; Auger, 2013) and ‘critical design’ (Malpass, 2013). The artefact in this sense provides a thought-provoking experience that integrates the viewer experience and deeper conceptual concerns regarding philosophical issues or alternative worldviews.

The above seven ‘family resemblances’ (Wittgenstein, 1953, 1998; Griffin, 1992) will be referred to in later description of projects (in Chapter 4 and Chapter 5) to illustrate how this research speculatively describes future Wundermaschinen.

3.6 Summary

In this chapter I have firstly reviewed some characteristics of historical Wundermaschinen in section 3.3. In section 3.4, I analysed and reflected on the contemporary ways of making to

propose a few experimental aspects. These two analyses have allowed me to speculate about the possibility of juxtaposing historical Wundermaschinen with contemporary technology to explore an idea of a '21st century Wundermaschine'. Seven family resemblance characteristics of speculative '21st century Wundermaschine' are proposed:

- Rarity and Refined Labour
- Information-oriented Visual Complexity
- Performance-like Setting for Specific Sensuousness
- Embracing Knowledge across Disciplines
- Assembling Multiple Epochal Technologies
- Machinery of Curiosity through Occurrent Processing
- Object of Philosophical Argument

They will be further developed through experimental projects in chapters 4 and 5.

Chapter 4 Developing Wundermaschinen of Correspondence

4.1 Introduction

Following the conceptual framework of 21st century Wundermaschine (discussed in Chapter 3), this chapter contextualizes practice-led research in two experimental projects. The main goal of this portfolio is to demonstrate the process of exploring one specific avenue for making contemporary Wundermaschinen, and to explore the potential contributions of this process. It particularly articulates how the practice of Wundermaschinen can be informed by media archaeology, especially by the implicit unrealized/forgotten dreams (explained in section 1.5.2) in media history.

Initially, section 4.2 will describe *Samsare Eye* (December 2012 – June 2013) which explored the experience of body, image and sound correlation in a body-mimetic installation. Section 4.3 will show how reflection and audience feedback for *Samsare Eye* led to a more focused review of ‘correspondence media’ in the history of technology. By ‘correspondence media’, I refer to media forms that embody an esoteric idea that there are relations between all things in the universe (which I will discuss in section 4.3). Based on the review, section 4.4 identifies three unrealized dreams for Wundermaschine practice: a ‘Wundermaschine of Correspondence’.

Finally, this approach will be reflected in the description of *Experiential Converter* (October 2013 – July 2014) (section 4.6), an artefact that embodies multiple characteristics of a 21st century Wundermaschine. Finally, this chapter will summarize this development of Wundermaschine of correspondence by suggesting its implications in the context of media art and technological developments (in section 4.7).

4.2 Experimental Project– Samsare Eye (Dec 2012 – Jun 2013)

4.2.1 *Methodology*

The making of *Samsare Eye* started with a notion to explore how a body responsive space could create wonder in the audience. The original aim was to create a lifelike eye that could interact with the viewers. A *Kinect* sensor and *Processing* library of SimpleOpenNI were thus utilized to achieve this goal (see section 4.2.4 for technical detail). This project was developed with some reviews on the history of correspondence media. It was also displayed in a show in Culture Lab for feedback and reflection (section 4.2.5). Based on this process of reflective prototyping, the design of the final version of *Samsare Eye* focused on creating a correspondent experience between the body gesture and the visual-sound experience. Implications for this research will be given in section 4.2.6.

4.2.2 *Aims and Developmental Context*

Samsare Eye (2013) was an interactive space constructed by *Kinect* sensor, laptop, projector and stereos. The primary aim of *Samsare Eye* (see Figure 23 and Appendix 3) was to construct a mechanism utilizing computational sensor technology that materialized the conceptual framework of 21st century Wundermaschine (described in section 3.5). Particularly, it aimed to embody characteristics that related to what I have discussed as ‘metaphorical’ (section 3.3.2), ‘emerging mimetic motion’ (section 3.3.3), ‘information-oriented visual complexity’ (section 3.5.2), and ‘embracing knowledge across disciplines’ (section 3.5.4). That is, by collecting and processing information on site and co-occurently, I created a space of metaphorical visualisation and mimetic motion to explore and provoke facets of wonder. It was also critical to investigate how this experiment could reveal further implications and potential practices.

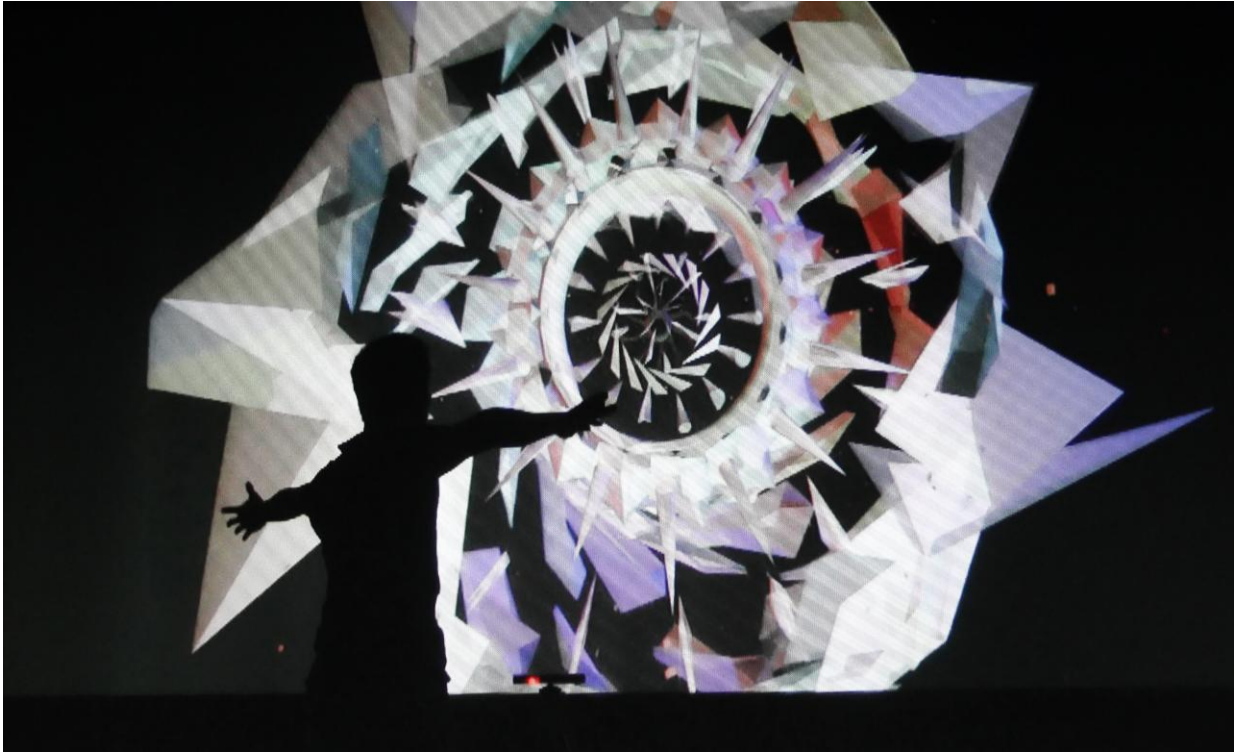


Figure 23 *Samsare Eye* and viewer interaction

4.2.3 *Design, Implementation and Aesthetics*

Working through a variety of concepts and designs, from a mirror-like experience to abstracted visual effects (Figure 24), a body-responsive eye was finally designed in which participants could experience changes of visual formation and sound by performing different gestures. This visualisation and interface was particularly designed to be metaphorical and to explore the features of emerging mimetic motion. As I have noted in section 3.3.2, what this practice took as metaphorical was an extraneous character that was often embodied in the design of canonical Wundermaschinen. The Wundermaschinen showed strong links to the ultimate realm of the era in which they were created, such as the divine or the regularity of life. The emerging mimetic motion, as I have contended (in section 3.3.3), was a creative inquiry that aimed to imply potential meanings for the essence of human life and intelligence, however they may have been shaped by what the designer took the value of life and intelligence to be. In *Samsare Eye*, I aimed to demonstrate observable qualities related to the achievement of

sensitivity of living through engineering. The technology was considered a responsive and meditative space that co-occurently reflects the viewer's body.

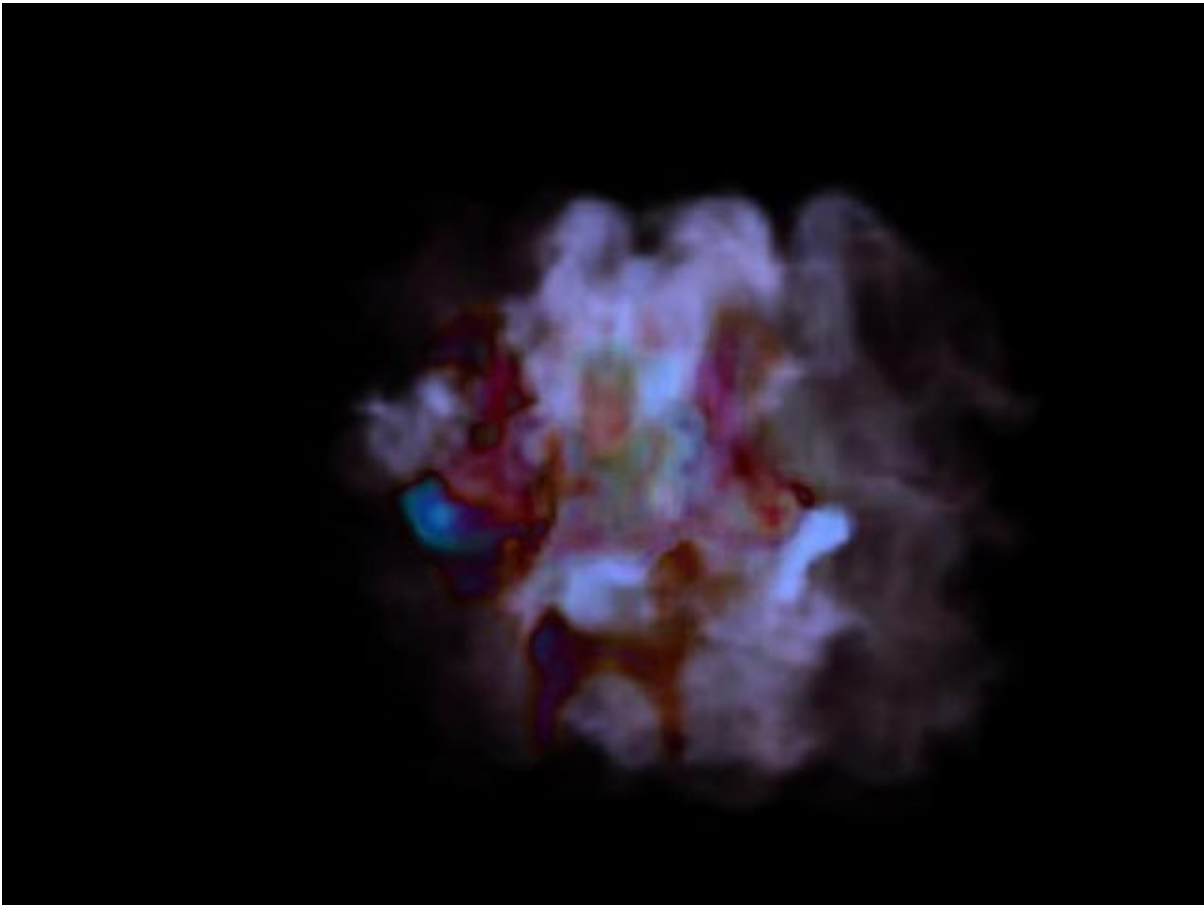


Figure 24 An abstracted visual effect designed and rendered using Maya in the experimentations during the development of *Samsare Eye*

4.2.3.1 *Religious-Metaphorical Visualisation*

In order to present a religious-metaphorical visualisation, two visual forms derived from Buddhism were applied in *Samsare Eye*: the shape of the *Mandala* and the repeated and fractured formations usually seen in the *Thangkas*. *Mandala* is a spiritual and ritual symbol in Hinduism and Buddhism, often representing a “microcosm of the universe” (Zhou, 2015)(see Figure 25). In various spiritual traditions, *Mandalas* have been employed for focusing attention of practitioners, as a spiritual guidance tool, for establishing a sacred space, and as

an aid to meditation and trance induction. They often exhibit complex rotational symmetry with the basic form of most *Mandalas* being a circle with several gates. According to Walcott (2006), these gates symbolically represent “rainbow bridges between the outer rims and the next layer of square walls – uniting relatively earthly with heavenly realms” (Walcott, 2006, p.75). The *Thangka* is a Tibetan Buddhist painting on cotton that usually depicts a Buddhist deity. The formation of repeated shapes (i.e. Deity Samvara with twelve arms and four faces) and varying numbers of elements (i.e. flower, fire) are often seen in *Thangkas* (Figure 26).



Figure 25 The 14th century Tibetan *Mandala* of Vajravarahi



Figure 26 Thangka of the Buddhist Deities Chakrasamvara and Vajravarahi. Mineral pigments and traces of gold on cotton cloth, around 15th century

4.2.3.2 *Emerging Mimetic Motion*

As Buddhist practice often takes the human body as a temple or dojo and treats body gesture as a critical part of what is spiritual, the two metaphorical imageries of deities in *Samsare Eye* were linked to the spectator's body to create a responsive and body-mimetic space. This design particularly aimed to reflect the review of each canonical Wundermaschine as a machine of real intelligence (discussed in section 3.3.3) that was shaped by its designer. In order to construct a responsive and intelligent space for spiritual practice, *Kinect* technology was applied to capture mimetic motion.

4.2.4 *Technical Description*

The design of *Samsare Eye* required me to learn novel assemblage skills and to acquire knowledge across several disciplines (section 3.5.4) including Buddhist imagery, 3D modeling, animation/sound design, and computer programming.

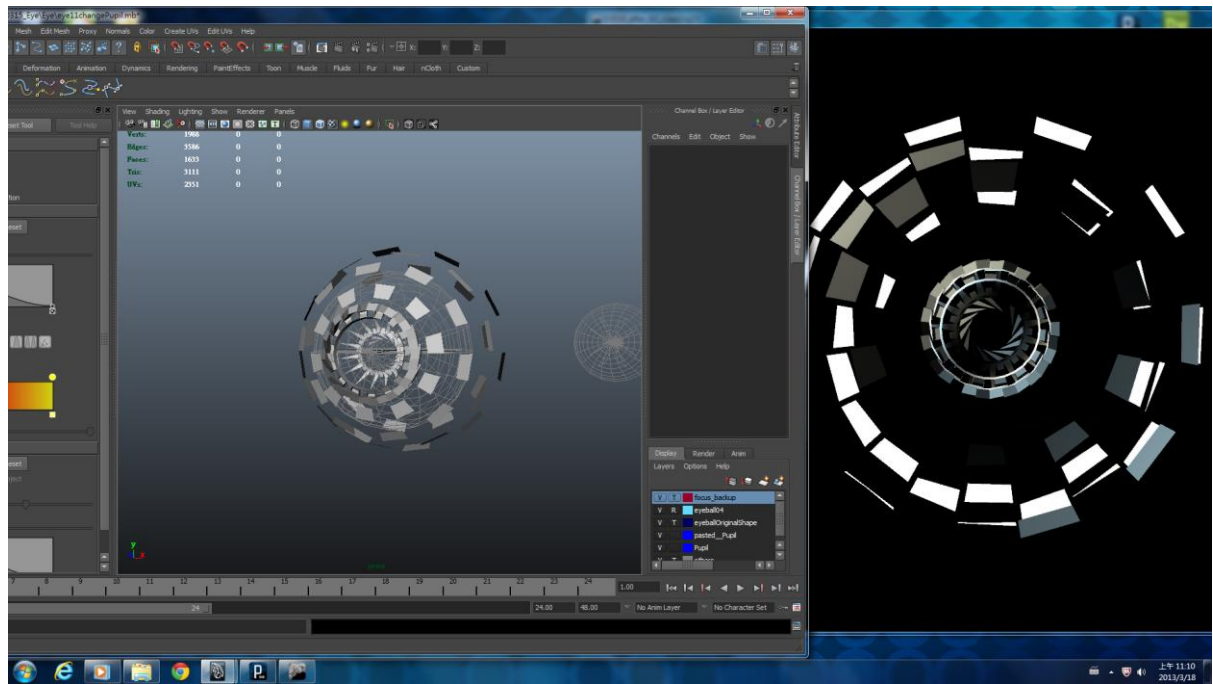


Figure 27 A screenshot showing the 3D Model design in *Maya* (left) and its preview in *Processing* (right)

4.2.4.1 *Religious-Metaphorical Visualisation: 3D Mesh Modelling in Maya*

Various images of *Thangka* and *Mandala* were imported into the software *Maya* as a reference for model design. A number of rotational symmetrical 3D meshes were created and intentionally positioned at different z depths. This was to create a multi-layered structure for the eye (Figure 27). By setting the colour hue and transparency of each fragment, and by moving each one of them with a sine wave pattern (through coding in *Processing*), the visualisation of *Samsare Eye* was made rich and generative.

Experimenting with the visual forms of *Mandala* and *Thangka*, and the imagery of the Awakened Eye in Buddhism (Franck, 1980), the visualisation of *Samsara Eye* gradually became a colourful and dynamic eye composed of multiple fragments that transform and change spontaneously. It aimed to be metaphorical by symbolizing communication with the divine through a meditative experience constructed in technology.

4.2.4.2 *Processing Sketch for Animation*

The 3D meshes constructed in Maya were imported into *Processing* with the *OBJLoader* library. An experimental 3D animation was made where the sound, colour and moving patterns were correlated. The default animation became a slow rhythmic swarm of shapes in which the colours of each fragments were constantly changing depending on their positions in the 3D space. This was achieved by generating three colourful spotlights in the 3D space through coding.

4.2.4.3 *Information-oriented Space: Kinect Sensor and Interaction Design*

In order to materialize an ‘information-oriented’ space (section 3.5.2), I hacked the *Kinect* sensor by applying the *Processing* library of *SimpleOpenNI* which made the sensor able to detect the viewer’s specific skeletal information. This was passed into an algorithm that created visual and sonic forms. The *Kinect* captured the positions of the participant’s hands, feet, torso and head. In order to create a smooth swarming motion, an algorithm was developed in *Processing* that constantly averaged the changing quantity of each point of position data (Figure 28). That is, the motion of the visualisation could remain smooth and steady even when the participant moved vigorously. By connecting the *Kinect* sensor-data with the

visualisation, the eye's formation changed smoothly in response to the viewer's body posture⁴ while the eye's colour hue and saturation also changed with the viewer's hand movements⁵. In the exhibition setting, the *Kinect* sensor was installed right below the visual projection for better tracking the viewer's body.

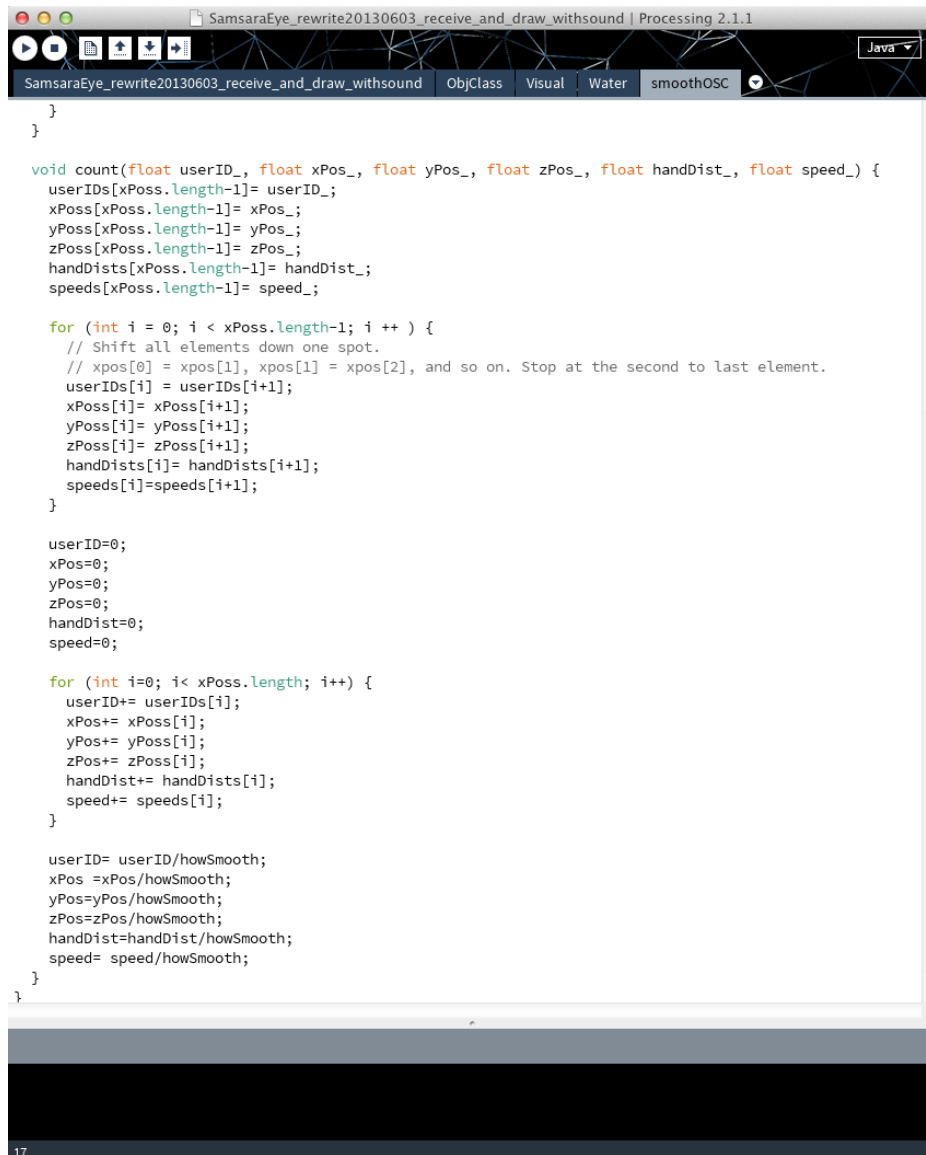


Figure 28 The algorithm in *Processing* that averages the changing position data

⁴ It expanded when the viewer's upper body leaned forward, and shrank when the viewer's upper body leaned backward. When the viewer tilted left, all fragments turned counter clockwise. When the viewer tilted right, all fragments turned clockwise.

⁵ The faster the hands were moving, the less saturated it became. If the hands were constantly moving with high speed, the colour of the animation became unsteady for a few seconds.

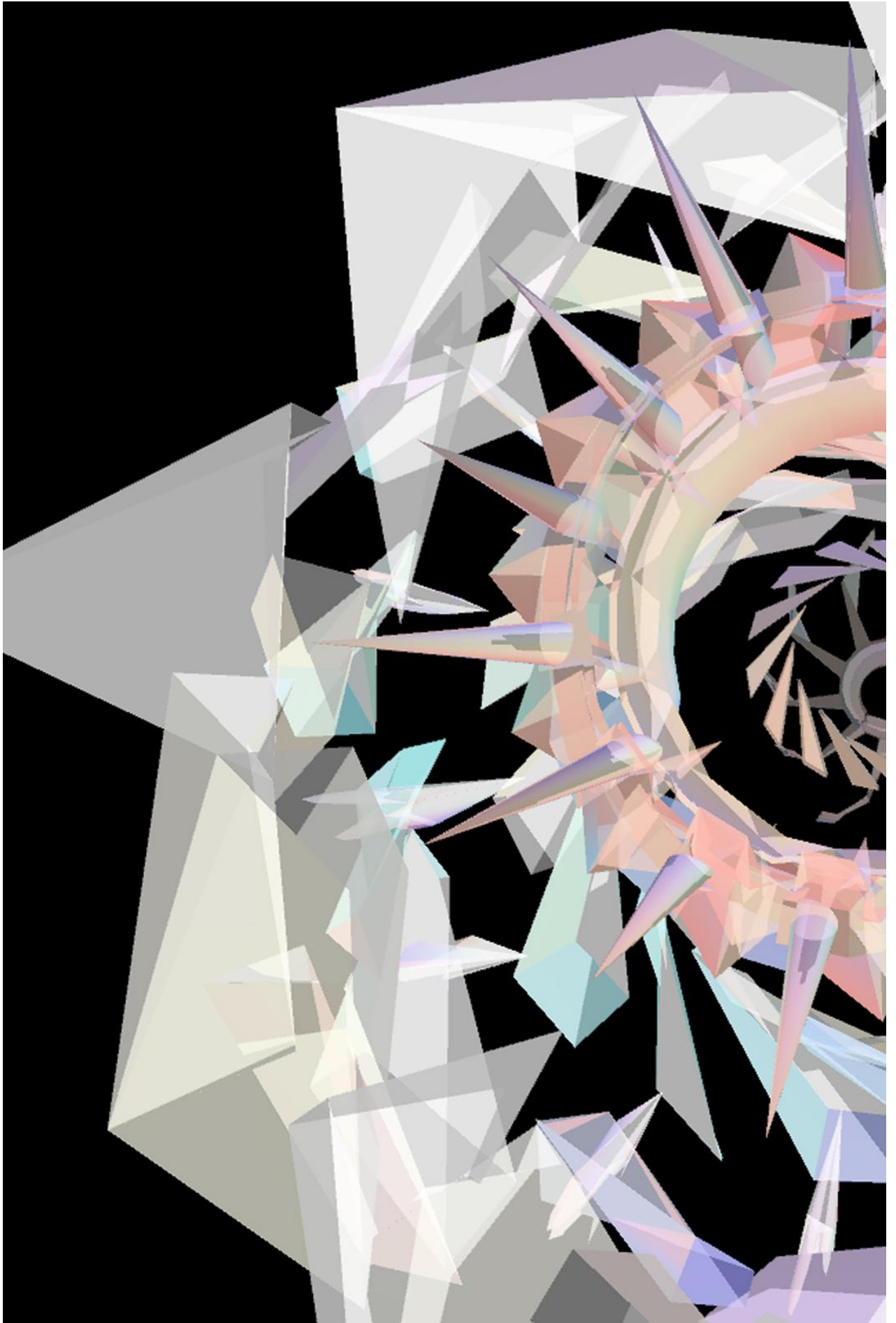
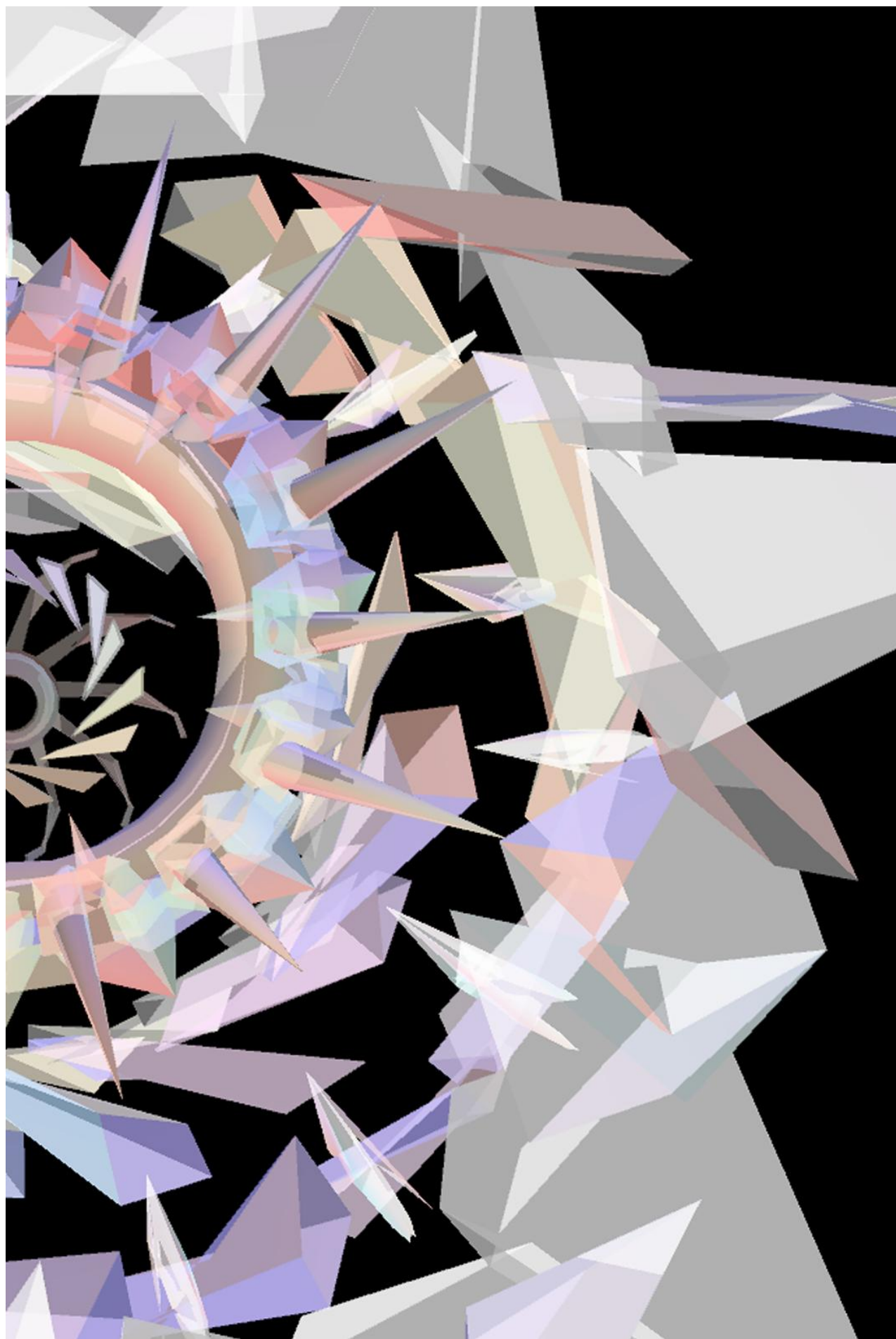


Figure 29 The Visualisation of *Samsare Eye*



For environmental sound, a sound pattern that was meditative and ambient was created. I downloaded some free sound tracks from website *FreeSFX* and *Jamendo* and re-mixed them in *Processing* to generate the primary sound pattern. This was done by using the sound filter of *Minim* library in *Processing* to cut off the high frequencies of the sound in response to the distance of the viewer's hands. Random sound effects (.wav files) were also triggered while the body was moving quickly forward/backward to provide more variety. In other words, the sound is constantly changing with all body movement. The aim was to create a multi-sensory, body-mimetic experience in the space.

4.2.5 *Audience Response and Self-reflection*

4.2.5.1 *Audience Response*

The final version of *Samsare Eye* was designed for a single participant for a meditative and reflective experience. *Samsare Eye* was first exhibited in Culture Lab in June 2013 and later was selected in the *Screengrab* New Media Art Exhibition and displayed at James Cook University in Queensland, Australia between July and August 2013. In addition, *Samsare Eye* was presented in a workshop at Newcastle University, U.K. in April 2014. The project received feedback from a number of sources. These pieces of feedback were documented or recorded during discussion with the participants.

All participants directly interacted with the work alone while spectators would sometimes observe from behind the installation. This pattern of social engagement challenged my initial assumptions about the work being a primarily solitary and meditative space. It showed

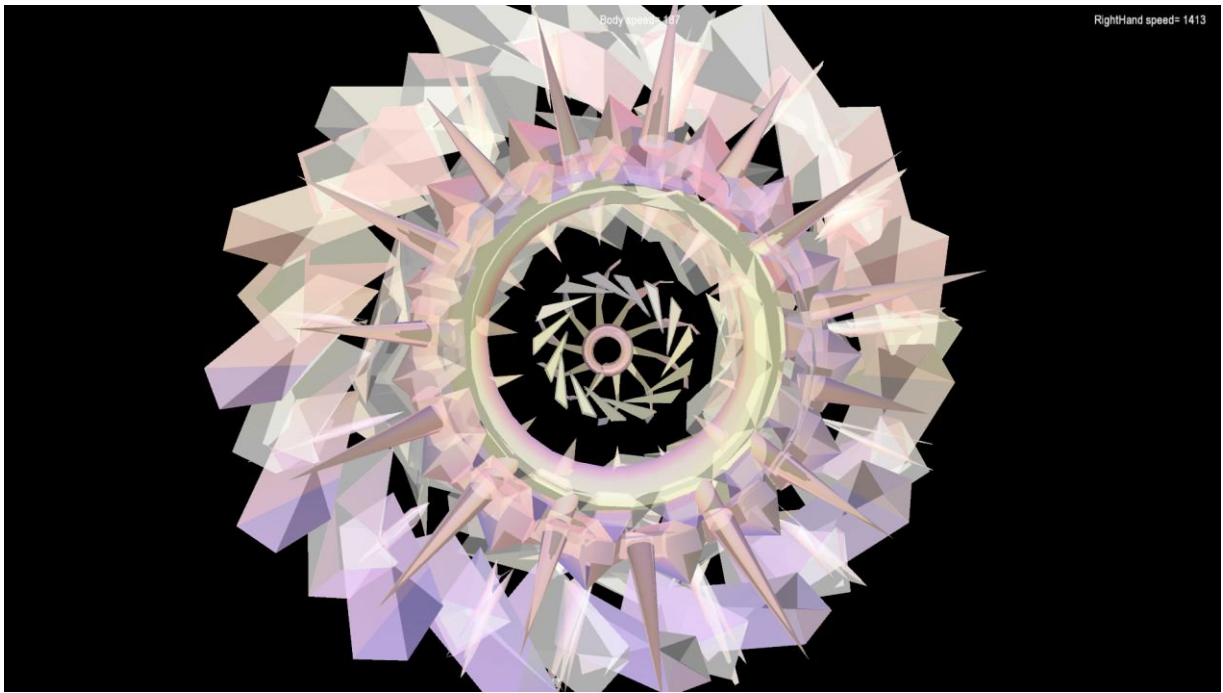


Figure 30 The colour and shape of the eye is responsive to the viewer's posture (see main text for explanation)

Samsare Eye's interface relied on the features of the exhibition space, such as how comfortable and secretive the atmosphere was, or how alone the participant was feeling. According to Reeves, Benford, O'Malley and Fraser (2005), the manipulation of *Samsare Eye* could be considered “partially revealing” (Reeves et al., 2005, pp.742–743) while the effects were “amplified” (Reeves et al., 2005, pp.742–743). This makes *Samsare Eye* an “magical public interaction” in the sense of Reeves et al. (2005, p.745). *Samsare Eye* ensures that the spectator is only aware of the effect. Interfaces tend towards revealing effects while hiding the manipulations that let to them. According to Reeves et al (2005), the participant's awareness of spectators may make them feel less meditative.

Most audience members expressed enthusiasm for the idea of a body-mimetic space prior to their actual engagement with *Samsare Eye*, and generally welcomed the opportunity to be standing and focusing on a responsive visual and sound environment. Most participants tried different postures to see the difference between them. The sense that the work was in some

way about, or related to them, seemed to be an important factor in sustaining their attention. One suggested this project might work as a tool for creative exploration among individuals since he commented *Samsare Eye*'s most interesting part was how it mimicked a 'correspondence' between different sensory organs and effects (sight, sound and body motion). He suggested such a notion of correspondence, which relates to ideas in European esotericism, was worth exploring further as it might lead to more creative contexts. Some thought that body exploration in a meditative, religious metaphorical space was intriguing. Most audiences stayed in *Samsare Eye* for a few minutes to observe and experiment with its visual complexity and the colourful swarming animation that responded to their own body.

Some mentioned that the visual form of the eye was not easily linked to the religious imageries I intended and the visual form was less significant in the experience, while the audience mostly focused on the responsiveness of sound, motion and colour. One of the participants commented that he saw this as an interesting interactive experience, but not a religious or meditative one.

4.2.5.2 Self-reflection

As the first experiment with a 21st century Wundermaschine in this research, *Samsare Eye* explored the means to create intelligent machinery that mimicked the participant's body in the form of a metaphorical visualisation. It generated a visual-metaphorical, body-mimetic and information-oriented experience where the viewer's body, visual and auditory experience were interlinked. This practice connects to what has been discussed in this thesis as 'Occurrent Awareness of Life', since *Samsare Eye* was able to collect information and process events as they occurred, allowing the mechanism to observe, react dynamically, and create wondrous effects on the recipient and space (as discussed in section 3.4.3.2). In this sense, *Samsare Eye* implied a potential for 21st century Wundermaschine practice: to create

mimetic motion through an information-oriented approach that connects the viewer's different sensory modalities.

Most interestingly, the audience feedback on 'correspondence', which was not expected for *Samsare Eye* in its initial stage, was considered crucial for future development. The main reason as that many audience members stated that they were most intrigued not by the meditation aspect or association of religious ideas but by some kind of abstract connection between visual, aural and kinesthetic perception. In section 4.3, I will further explore this idea of correspondence, its implications for arts, science and esotericism, and how it can influence artefact design through computational means.

4.2.6 ***Implications: Toward a Media Archaeology of Correspondence Media***

The experiment of *Samsare Eye* reflected on the interest of experimenting with the 'metaphorical' and 'mimetic' facets of canonical Wundermaschinen and the 'information-oriented' aspects of computer-assisted fabrication as I have stated in Chapter 3. Through this experiment, new inquiries emerged. They include the following: Do new characteristics of wonder created by computational artefacts (such as the contactless body-response of *Kinect*) inevitably lead to the neglect of canonical ones, such as the visual quality of refined craftsmanship and labour? How could computational artefacts embody a family resemblance to canonical Wundermaschinen in a way that is more 'epochal' (in the sense of section 3.5.5)? These questions motivated this study to consider the possibility of bridging computational information visualisation with a cultural-historical orientation. Therefore, the following two sections will describe an understanding of correspondence and the media archaeology of its relationship with technology, and the excavation of three implicit unrealized dreams in media history that motivated my next practical steps.

As I stated in the methodology section, this attempt to shift attention somewhat away from a narrative history of the apparatus and to focus on the imaginaries and dreams for a specific media design has been adopted by contemporary media theorists (Kluitenberg, 2011; Huhtamo & Parikka, 2011; Zielinski, 2006). According to Kluitenberg (2011), this proposed archaeology of the imaginary is not to establish a set of progression of technological imaginaries. Rather, it is to “study these imaginaries in action across different historical and discursive settings and contexts” (Kluitenberg, 2011, p.49). To shift attention to the domain of the imaginary and the so far unrealized can reveal how permeable the boundaries between the domains of the imaginary and realized media can be, and how both domains continuously help constitute each other. As Kluitenberg (2011) argues, these unrealized imaginaries of apparatus are not simply ‘fictional’. Since the imaginaries and the realized in the history of media continually weave in and out of each other, the imaginaries can serve to:

“... retain the utopian moment that unveils itself when aberrant trajectories in the development of technology and the media are recognized.” (Kluitenberg, 2011, p.67)

Accordingly, the following excavation of historical correspondence media aims to explore a more practical and developmental context for a ‘Wundermaschinen of Correspondence’.

4.2.7 *New Knowledge Occurred in the Making*

The making of *Samsare Eye* suggests how object-oriented-programming skill can largely benefit an interaction design which incorporates responsive sound, body interaction and 3D visualisation. I suggest future makers to design their artwork under such logic for easier problem solving. Please see Appendix 12 for more details.

4.3 From Correspondence Media to Unrealized Dreams

Throughout history, the idea of correspondence has played diverse roles in philosophy, natural sciences, art theory, and music theory. Different notions of correspondence in the history of technology show a variety of procedures for developing correspondence models. Adopting a media archaeological tendency for “studying recurring cyclical phenomena that (re)appear and disappear over and over again in media history, and to transcend specific historical contexts” (Huhtamo, 1997, p.222), I will group the correspondence media depending on their various relationships between correspondence and technology. This discussion will highlight the cultural motives that guided the development of correspondence media, and finally reveal three unrealized dreams (in section 4.4.) for future practice.

4.3.1 *Correspondence Media for Disclosure of Regularities in Nature: Mundane Monochord*

Around 550 B.C, with the elaboration of the theory of mathematics, music and astronomy, Pythagoras and his followers offered mathematical equations for the musical scales, showing that musical notes could be seen as having a relationship to numbers. The Pythagoreans also believed that the planets and stars moved according to mathematical equations which corresponded to musical notes and could thus produce a symphony (Riedweg, 2005). The higher endnote of an octave could be deemed the mathematical doubling of the frequency of the lower two notes, and the interval of an octave was rooted in the ratio 2:1. Plato, following Pythagoras in about 370 B.C., proposed the idea that mathematics and abstract thinking were a basis for philosophical thinking in science and morals. According to Hare & Barnes (1999), Plato and Pythagoras shared a mystical approach to the soul and its place in the material world. For example, in *Timaeus*, Plato described the soul of the world as having “musical ratios” (Plato in Cornford, 1935, p.69). A cosmological system of correspondence emerged in which the planets’ radii were set with a ratio sequence of 1:2:3:4:8:9. Later, variations would

emerge with the following ratio sequence: Moon = 1; Venus = 2; Earth = 3; Mars = 4; Jupiter = 14; Saturn = 25 (Day, 1999, p.174). This sequence approximated the Greek diatonic musical scale's ratios and therefore described the planets with a concept of *Musica Universalis* (the music of the spheres) – an ancient philosophical concept that regards proportions in the movements of celestial bodies as a form of music. This music was not usually thought to be literally audible, but a rather harmonic and mathematical concept for approaching the hidden regularities of the world.

It was the works of Plato's pupil, Aristotle, which were translated and incorporated into European sciences and set the stage for a later scientific equating of light spectra, celestial motion and sound frequencies. For example, in 1619, Johannes Kepler published *Harmonices mundi* (Harmonies of the World). In this book, Kepler established his celestial-harmonic model that related musical consonance and the angular velocities of the planets. Each planet was not only given an individual basic note but was given a sequence of musical notes based on its movements. The non-audible, silent regularities of nature as a mathematical relationship studied by Pythagoras, Ptolemy and many others before Kepler, demonstrated humankind's interest in understanding the macrocosm of regularities (the nature, universe) through the microcosm of regularities (movement, sound). This was the ground motive of the theory of correspondence.

Athanasius Kircher and Isaac Newton later took up this theory of correspondence between music and natural phenomena founded on mathematical principles as the model in physics for theories of colour and, further, the basis for establishing the harmony or disharmony of colour combinations. For example, Kircher not only created symbolic classifications but was also the first to allocate colours to tone intervals. In 1650, Kircher set out his views on music in his book *Musurgia Universalis*. By succession from Pythagoreans' doctrines, he maintained the

medieval idea that the harmony of music reflected the proportions of the universe, and could also, through correspondence within the body, connect the heavens and the natural world:

“... the nature of things in all respects observes musical and harmonic proportions, and that even the nature of the universe is nothing other than the most perfect music.” (Kircher, 1650, p.364)

One of the most intriguing correspondence media that embodies a cultural desire for an instrument as a disclosure of the regularities of nature was the *Mundane Monochord* designed by Robert Fludd in 1618 (see Figure 31). Fludd designed the one-string instrument to describe the regularities of the world. In principle, Fludd followed the discovery by Pythagoras, that the division of a single string in ratios of small whole numbers (e.g., 1:2, 2:3, 3:4) could produce musical intervals, which composed in the harmony of a song could emotionally move the listeners and touch their spirit (Zielinski, 2006, p.105). Following Pythagoras' scales to determine the series of intervals, the string of Fludd's monochord extended over two octaves of a tone and at its exact midpoint laid the division (also called bridge) between the two octaves. When the string was open it vibrated at a given frequency and produced a pitch. When the length of the string was halved, it produced a pitch an octave higher. That is to say, with the two octaves and the three simple ratios (of 1:2, 2:3 and 3:4), even those with no musical training could recognize the musical intervals that made up the basic system of consonance/harmony.

correspondences (Zielinski, 2006, p.107). As we can see (in Figure 31), Fludd understood his world as a monochord, a harmonious construction with multiple variations and sections based on the correspondent relationship between elements (such as Ignis, Aer, Aqua and Terra), and between proportions of sound and celestial motion in different seasons. He attempted to encompass the great variety of relations of the world (macrocosm) in a simple and symbolic form (microcosm): a form of music instrument, by which the abstract principle of correspondence was perceived through aural experience.

More interestingly, Fludd declared God to be the highest and ultimate authority for the correct tuning (of the world) which was not communicable through numbers. Therefore, Fludd's monochord could connect human players and listeners, not only through an aural experience, but through evoking a principle of the Divine. As Zielinski suggests:

“In his model of the world as monochord, the Divine principle has to take the dynamic path through dark matter so that diversity of form can arise. Applied to music, this process can be conceived of as the experience of the listener.”
(Zielinski, 2006, pp.109–110)

This motive of media as a pursuit of the spiritual and the harmony will be further explored in section 4.4.2.

From the perspective of the contemporary media practitioner, Fludd's monochord clearly embodied a dream of a dual instrument (Novak, 2007) that incorporated the characteristics of a scientific instrument and a musical one. As a scientific instrument, it demonstrated through a specific design the regularities and mathematics behind the world of experience, and showed how humankind could define the measurement of space and sound, and produce finer divisions in musical tones and intervals. On the other hand, as a music instrument, it

embodied a unique form of performance: not concerned with flowery melodies, but simple, recognizable tonal gradations for resonant and meditative experience. Fludd's dual instrument not only illustrated the heavenly principles governing the intervals so that the players could tune the instrument, but also showed how the disclosure of regularities of nature could be embodied in a 'performance-like' (section 3.5.3) media form.

However, limited by the technology then, Fludd's *Mundane Monochord* could only present the symbolic relationship between sound and celestial motion, without being able to show them 'co-occurently'. For this research, the excavation of Fludd's *Mundane Monochord* revealed an unrealized dream of correspondence media that could be engaged with the computational: a dual instrument (scientific-musical) that concurrently displays the regularities of correspondence in nature and searches the aesthetic potential of such performance-like experience. The implication of this unrealized dream will be explained in section 4.4.1.

4.3.2 ***Correspondence Media for the Pursuit of Harmony: Bishop's Colour Organ***

In Fludd, the correspondence media embodied a cultural dream to explore the spiritual and the harmony between human and nature. By the 1920s, the previous (natural philosophical) idea of the scientific was almost abandoned: many of the historical physics experiments and perception-based prerequisites for colour-sound analogies had been gradually proven incorrect. The parallel between colours and musical notes was held only as analogical concordances, and the notion that there was any physical principle of connection between them had been discarded. More particularly, from the perspective of modern physicists, there were several difficulties regarding any correspondence scheme based on the mathematical calculation of colour-sound analogy. These include the following: Firstly, the waves of sound

and light lack a common physical foundation, since in contrast to mechanical sound waves, light waves are electromagnetic. Secondly, the progression of colors is arithmetical, whereas the progression of tones is logarithmical (Jewanski, n.d.). These issues led to further criticism with regard to the creation of a scientific colour-sound correspondence pattern during the nineteenth and twentieth centuries. More practitioners moved away from a scientific notion of correspondence to a 'spiritual' or 'aesthetic' one: a pursuit of the harmony of human senses in various media forms.

For example, modern painter Wassily Kandinsky experimented with the analogous relationship between music and painting and searched for a colour harmony that rested on a "corresponding vibration in the human soul" (Kandinsky, 1977, p.27). Roy De Maistre also expressed a desire to seek an ultimate scheme of "synthetic spiritual progress" (Wakelin, 2006; Alderton, 2011). Experimental filmmakers John and James Whitney worked with analog and later digital technology from the 1940s through the 90s to create abstract films designed to correspond to musical forms and meant to suggest "spiritual states of consciousness" (Wees, 1992, pp.137–146).

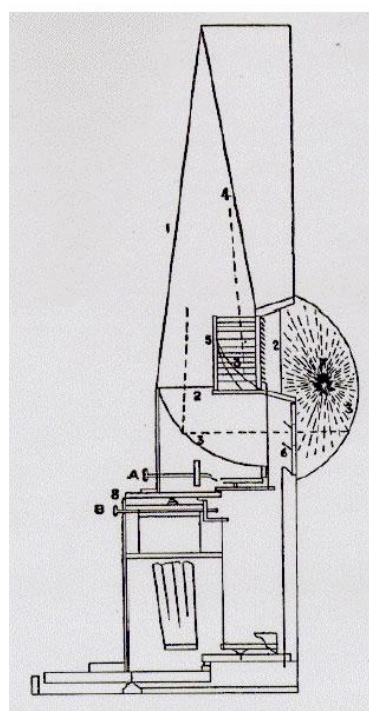
In this research, the most unique example of correspondence media searching for the harmony of the human spirit was American inventor Bainbridge Bishop's design and thesis of the colour organ:

"Some time in the future this colour-science will be recognized and adopted. It will be used with music for divine worship. It will also be employed in teaching music and art." (Bishop, 1893)

As early as 1877, Bishop had been particularly interested in colour harmonies and the concept of painting music. With the goal of creating harmonious colour in an analogous manner to

harmonious music, he built a musical instrument by constructing a light producing apparatus that was to be placed on top of a home organ (see Figure 32).

The light producing apparatus consisted of a system of levers and shutters allowing coloured light to be blended on a screen while music was performed. A large ground glass, framed like a picture, was set in the upper part of the instrument. The instrument had little windows glazed with different coloured glass. Each of the little windows had a shutter so that by pressing the keys of the organ, the shutter would throw back and let the coloured light through. This light, diffused and reflected on a white screen behind the ground glass produced



1. Ground glass tablet.
2. Ground glasses to diffuse light.
3. Reflectors.
4. White screen.
5. Upper sash.
6. Lower sash.
7. Electric light.
8. Keyboard.
- A. Color-stop for keyboard.
- B. Color-stop for pedals.

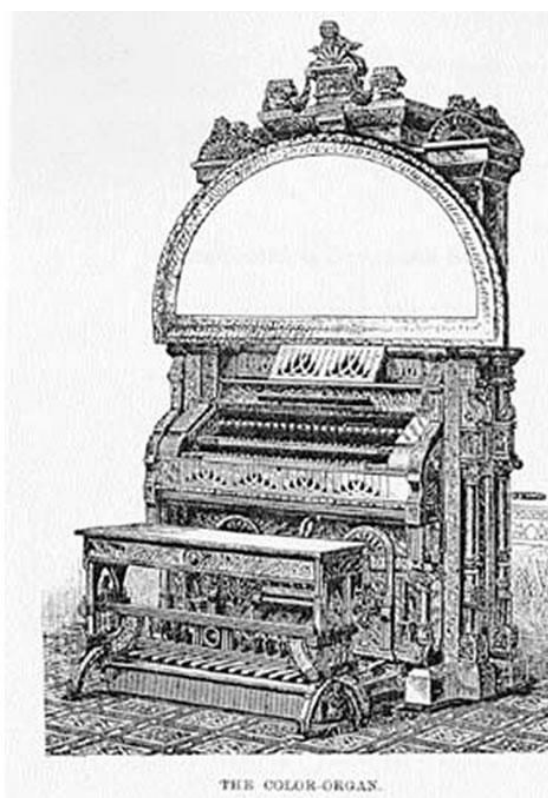


Figure 32 Model and exterior of Bainbridge Bishop's Colour Organ. Image from: Bainbridge Bishop, "A Souvenir of The Colour Organ" (1893)

a colour that was softly shaded by the tint of the glass. Therefore, chords could be shown visually:

“Chords were shown properly, the lower bass spreading over the whole as a ground or foil for the other colours or chords of colour, and all furnishing beautiful and harmonious effects in combination with the music.” (Bishop, 1893)

Bishop claimed that simple colour did not give the sensation of a musical tone, but a colour softened by gradations into neutral shades or tinted grays did so. As light was the fundamental element for making a harmonic series or chord, it was possible to evolve a new “science of harmony of light” (Bishop, 1893) somewhat analogous to music and the harmony of sound. In contrast to Newton and Kircher, Bishop constructed his colour (light) theory alongside an empirically-oriented study: a colour-sound analogy based on phenomenological observation of natural phenomena:

“The natural harmonic chord of light, as illustrated by the rainbow, shows red as its fundamental or keynote; for this reason I think we should take C, the key-note of the natural scale. It will be observed that its dominant is greenish-blue, its subdominant yellow-green. The greens of nature seem to make up combinations and masses of greens inclining to these two hues. A pure crude green seems to be out of place in a landscape, and, if seen, it generally produces a harsh and discordant effect.” (Bishop, 1893)

And with this approach Bishop also connected music and colour by their similar melancholy effect on the perceiver:

“Violet-blue always gives me a sad impression similar to the music played in A minor. This will be observed in viewing distant violet-blue mountains at sunset or twilight. The melancholy effect is strongest when the dominant or subdominant colour of the minor key is present, yellow and orange; one of which colours we commonly see at such times above the mountains.” (Bishop, 1893, p.9)

Prior to Kandinsky’s later analogical approach in *Concern the Spiritual in Art*, Bishop obviously attempted to seek the ‘melancholy effect’ of sound and colour through their corresponding relationship. Bishop’s colour organ showed the general influence of a theosophical movement led by Helena Blavatsky, which concerns humanity’s spiritual development within a coherent cosmology (Blavatsky & Goodrick-Clarke, 2004, p.195).

The most significant aspects of Bishop’s colour organ to this study include the following. Firstly, his theory of colour-light harmonies was based on empirical observation of the natural phenomena and the melancholy effect of the colours. Secondly, he constructed a supplementary device that was to be placed on top of a home organ to co-occurently display colour-sound correspondence. Here it becomes evident that regularities of colour-sound harmony can be sought not in the sphere of a physicist’s analogical scheme but on the basis of the imaginary and divine dimension of such correspondence technology. So, drawing on Bishop, I ask: how can we pursue the spiritual and the harmonic through making a supplementary device for common technology (such as a computer)?

The fact that Bishop’s colour organ was quite limited by the technology of his time also makes a contemporary exploration more intriguing. For example, Bishop’s colour organ could not display accurate colour-light gradations for all musical tones, since his colour organ could only assign one shutter for each key, and also relied on a back window to provide a light source, which could be highly influenced by atmospheric conditions. The influence of the

unrealized dreams of Bishop's colour organ on this research will be further explained in section 4.4.2.

4.3.3 ***Correspondence Media for Communication with the Incommunicable: Eyeborg***

Multiple neurological studies in the field of 'sensory substitution' (Bach-y-Rita & W. Kercel, 2003; Poirier, De Volder & Scheiber, 2007; Ward & Meijer, 2010) demonstrate the capacity of the human brain to adapt to information relayed from an artificial receptor. For example, Ward and Meijer (2010) reported proof of visual experience in blind users of a sensory substitution device called *vOICe*. By extensive use to develop expertise, Ward and Meijer's research concludes that visual information can be provided to blind users through electronic devices that convert images into sound. It is also recognized that once established, the sensory substitution mapping between the auditory and visual domains is not confined to when the device is worn and, thus, may constitute an example of "acquired synaesthesia" (Ward & Meijer, 2010, p.492). As many have argued, visual to auditory sensory substitution in devices like *vOICe*, provides an abstract "contingency learning system" (Proulx, 2010; Ward & Meijer, 2010) as a function of the conversion of images into sound. According to the researchers, the contingency learning system is the automaticity aroused when a person learns to associate multisensory information. This field of sensory substitution provides the opportunity to develop practical devices for persons with sensory loss.

Born with the inability to see colour, artist Neil Harbisson collaborated with cyberneticist Adam Montandon and later with software developer Peter Kese to design *Eyeborg* (Figure 33), a sensor device that could transpose colour frequencies into sound frequencies. In 2004, *Eyeborg* was permanently osseo-integrated inside Harbisson's skull and sprouts from within his occipital bone. The electronic device has allowed him to hear the light frequencies of the

spectrum including invisible colours such as infrareds and ultraviolet. Claiming himself to be a cyborg artist, Harbisson (2013) said:

"The sounds are transmitted through my bone to my inner ear, which allows me to interpret what colours are according to the different sign waves of each sound."
(Ross Bryant, 2013)

By developing this sensory substitution device as well as other experimental projects, Harbisson proposed that his technology could be integrated into the body to extend our abilities, knowledge and perception of reality (Ross Bryant, 2013). For example, *Piano Concerto No. 1* was Harbisson's performance of a colour concert, in which he painted a grand piano with different colour paints and used his *Eyeborg* to play the frequencies of the colours. *Sound of Portraits* was a project that created a microtone chord for each person depending on his/her facial colours. To create this sound portrait he stood in front of the person and pointed



Figure 33 Neil Harbisson and his *Eyeborg*, a device that can transpose colour frequencies into sound frequencies

his *Eyeborg* at the different parts of his/her face, then wrote down the different notes on special 360 lined manuscript paper.

For this research, Harbisson's *Eyeborg* is a contemporary design that embodies a reappearing dream of correspondence media. It demonstrated an instrument (converting colour to sound) that was particularly designed to communicate with the incommunicable (i.e. Divine, sensory loss patient). It showed how technology could support the creation of a potential language, and how the computational has helped facilitate such technology.

However, turning to the family resemblance of Wundermaschinen, *Eyeborg* seemed to show less facets of wonder of the canonical Wundermaschinen I have discussed (in section 3.3 and 3.5.). *Eyeborg* can be considered a successful information-converting design for a single wearer. It can turn colour into sound effectively. Yet, the limited possibility of improvisation in the colour-sound transposing process make it less engaging, if compared with *Mundane Monochord* or Bishop's colour organ. The wearer could only explore the experience between colour-sound conversions. However, the wearer may easily miss the rich imaginary and cultural-historical relationships in correspondence technology (which are critical to Wundermaschine design as discussed in section 2.3.7). Harbisson's *Eyeborg* was considered in this research to contribute more to the support of cyborgism as an art current and to neuroscience research than to the revelation of the potentiality of correspondence as a facet of wonder. Therefore, for this research, the review of *Eyeborg* reveals another unrealized dream in correspondence media for communicating with the incommunicable. As a functional design of inter-sensory communication, *Eyeborg* seems to discourage deeper exploration of the cultural-historical notion of correspondence. This will be further discussed in section 4.4.3.

4.4 Three Unrealized Dreams of Correspondence Media

In section 4.3, this research ventured into the realms of both the realized and the imaginary of correspondence media. This helps identify several unrealized dreams that may be as revealing as realized artefacts or instruments. For scholars such as Kluitenberg and Zielinski, the imaginaries of media are related to media archaeology, since they are a common ground for focusing on the past as a resource for rethinking the way we approach modes of perception, sensation and the creation of media (Kluitenberg, 2011; Kluitenberg et al., 2007; Huhtamo & Parikka, 2011; Zielinski, 2006). Therefore, in this section, I will focus on those historically recurring patterns of imaginaries of correspondence media, of both the realized and unrealized, and apply them as a means for countering ideas of technological progress. Through this, I offer critical implications for future practices of Wundermaschinen.

4.4.1 *Dual Instrument for Co-occurrent Phenomena*

A review of Kircher and Newton's experiments on colour theories and Fludd's *Mundane Monochord* (in section 4.3.1) identified that there was an unrealized dream of a dual instrument for co-occurrent phenomena in correspondence media. For example, *Mundane Monochord* was claimed by Fludd as a design to demonstrate the order of things in the universe. However, limited by the technology then, *Mundane Monochord* only presented the sound tones with relating elements in a 'symbolic' instead of 'co-occurrent' means.

As stated in section 4.3.1, a dual instrument should, on the one hand, embody a scientific notion of analytic composition or measurement: a device to disclose the regularities between multiple phenomena, such as the synthesis of sound tone and colour. On the other hand, it should embody a musical/expressive notion of performance: an improvisational device that realizes the visual and aural correspondence via generative means and can be used for expression. The craft of the instrument in this case would involve considerable technical skill

in building a system or artefact that realizes a multi-sensory environment in a ‘co-occurrent’ setting.

The creation of *Experiential Converter* (in section 4.6.) will thus aim to tackle the following questions. How can we materialize this unrealized dream in the practice of contemporary Wundermaschine? Can the disclosure of the regularities of phenomena become the focus of artefact/instrument design, in the hope of allowing a rich and dynamic aesthetic exploration?

4.4.2 *Subtle Light Organ for Spiritual Resonance*

Bishop claimed that light was the fundamental element for making a harmonic series or chord, and it was possible to evolve a new “science of harmony of light” somewhat analogous to music and the harmony of sound. There seems to be a connection between Bishop’s work and Jewish Kabbalah which makes light the fundamental element and means by which the divine is present (Wolfson, 2004).

Bishop (1893) presented the intention to build a supplementary instrument (on top of home organ) for divine worship. We see the underlying dream of constructing a subtle device that turns common technology into a spiritual artefact. However, limited by the technology then, Bishop’s colour organ could not display accurate colour-light gradations for all musical tones, since his colour organ could only assign one shutter for each key, and also relied on a back window to provide a light source. Bishop was unable to create accurate correspondences for the subtle gradation of the sounds of nature. This makes the notion of generating subtle light relating to sound an unrealized dream in such ‘spiritual technology’. How my work attempts to materialize this unrealized dream will be tackled in the practice of *Experiential Converter* (in section 4.6).

4.4.3 *Apparatus for Communicating a Cross-modal Language in a Cross-cultural Setting*

In the work of Kandinsky and De Maistre, there was a common intention to formulate a vocabulary of visual art comparable to the rules and structures of music composition. Their intention to compose abstract art that was universally comprehensible and independent of cultural, political or historical contexts was considered by art historians as a common notion of “abstract art as universal language” (Brinkmann, Commare, Leder & Rosenberg, 2014). The review of *Eyeborg* in section 4.3.3 also showed the intention of universal communication through technology: a device that converts colour into sound in a way so that people can understand each other across language/sensory barriers. However, in a research toward Wundermaschinen, it is understood that the correspondence media to ‘communicate with the incommunicable’ should not be limited to linguistic communication and the effectiveness of colour-sound conversion. This research should prototype Wundermaschinen that create depth of experience. The communication is not concerned a limited idea, but should be extended and explored instead.

The media archaeology reveals that the notion of formulating a ‘cross-modal language in a cross-cultural setting’ was still concerned with an unrealized dream, ascribed to, or projected onto actual correspondence media both by their designers and the public. As Kluitenberg (2011) suggests, the transition between imaginary and actual media instruments, in terms of their signification, is seamless. This unrealized dream shows fictional imaginaries of correspondence media for contemporary Wundermaschine practice. Therefore, I ask the following questions: How can the dream of communicating cross-modal language in a cross-cultural setting be realized through a machine-prototype that converts art images into sound and kinetic motions with a perceivable process? How can art images from various cultural and historical backgrounds collaboratively generate a correspondence experience with

an intention of universality and clarity in reality? The practice of *Experiential Converter* (in section 4.6) will further tackle these questions.

4.5 Toward Wundermaschine of Correspondence

As I stated in Chapter 3, the aim of this research is to construct contemporary Wundermaschinen, that is, creative artefacts that inherit the emerging experimental aspects of computer-assisted fabricated machines (section 3.4.3) and the family resemblance characteristics of canonical Wundermaschinen (section 3.3 and 3.5). Such artefacts aim to be metaphorical and aesthetic-potential. The reflection on *Samsare Eye* (section 4.2) and the media archaeological review of correspondence media (from section 4.3 to 4.4) further identified a more specific and potential framework of ‘Wundermaschine of Correspondence’, which is a design that fosters humankind’s interests in the disclosure of the regularities of nature, the relationships between phenomena, and the pursuit of specific techno-historical dreams in media history. That is, dual instrument for co-occurrent phenomena, subtle light organ for spiritual resonance, and apparatus for communicating cross-modal language in a cross-cultural setting. The following section will demonstrate the developmental context, design aesthetics, and implications of a Wundermaschine prototype that materializes this media archaeological excavation of correspondence.

4.6 Experimental Project – Experiential Converter V.1 & V.2 (Oct 2013 – Jul 2014)

4.6.1 Methodology

The making of *Experiential Converter* aimed to see how the conversion between sensor data, such as sound, colour and motion could engender wonder. It started with some experiments on constructing a colour-reading mechanism. *Processing*, *Arduino* and *PureData* were thus utilized to achieve this goal of data conversion through OSC communication (see section

4.6.4 for technical detail). The making process was then accompanied by a review of correspondence media in history to see parallels and potential discussions between the contemporary and the canonical (explored in section 4.4). It was then focused on tackling the unrealized dreams through practice (see section 4.6.5 – 4.6.7 for detail). Different versions of *Experiential Converter* were displayed in Culture Lab for feedback and reflection (section 4.6.8). Based on the feedback and reflection, the implications of this practice will be suggested in section 4.6.9 and 4.6.10.

4.6.2 *Aims and Developmental Context*

The practice of *Experiential Converter V.1* (as installation, see Figure 35 and Appendix 4) and *Experiential Converter V.2* (as performance, see Figure 34 and Appendix 5) were both experiments in how an artist could materialize a Wundermaschine that tackles the unrealized dream of correspondence media (excavated in section 4.4). Prototyped with computer-assisted tools, it also attempted to explore several characteristics of 21st century Wundermaschine: ‘rarity and refined labour’ (section 3.5.1), ‘information-oriented visual complexity’ (section 3.5.2), ‘performance-like setting for specific sensuousness’ (section 3.5.3) and ‘machinery of curiosity through occurrent processing’ (section 3.5.6) by utilizing emerging fabrication technologies.

4.6.3 *Design, Implementation and Aesthetics*

In order to create a co-occurrent colour-sound correspondence in a performance-like setting, *Experiential Converter V.1* was designed as a supplementary device attached to a laptop that could convert an image into multiple correspondent experiences (colour, sound and motion). *Experiential Converter V.2* was particularly designed as an instrument for a musical performance. Both designs showed the intention to engage the three unrealized dreams excavated in correspondence media in section 4.4. As an artefact fabricated by

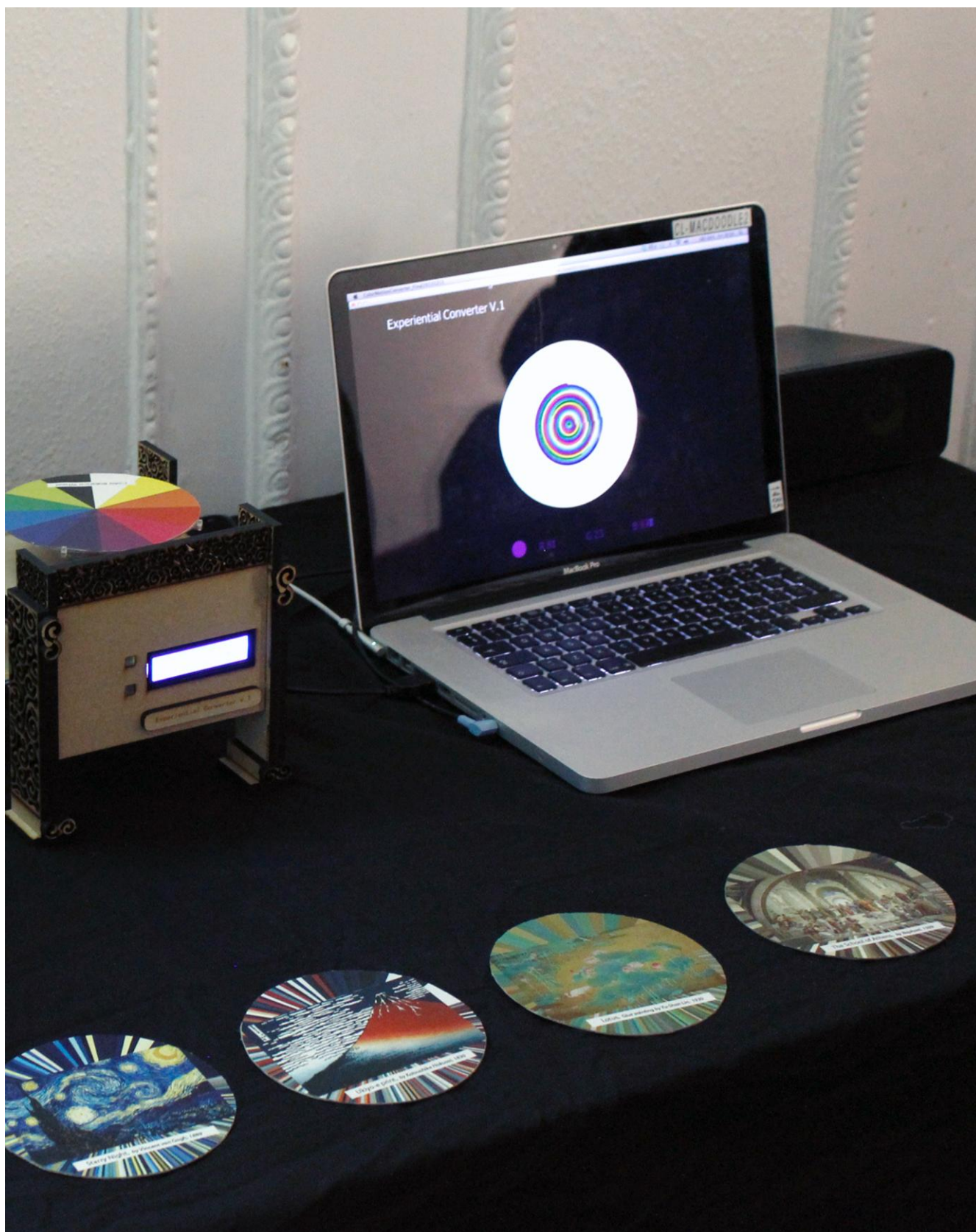
computer-assisted tools, the design aesthetics of *Experiential Converter V.1* aimed to possess visual details to display ‘rarity and refined labour’ (section 3.5.1). The details were designed in *Illustrator*, materialized by carving medium-density fibreboard (MDF) in a laser cutter and assembled by hand. A visual aesthetics of Jianzhi, a traditional style of papercutting in China was adopted to arouse curiosity (see Figure 36 and Figure 37).



Figure 34 The performance of *Experiential Converter V.2*



Figure 35 The exhibition setting of *Experiential Converter* in W.I.P. Show in Culture Lab, Dec 2013



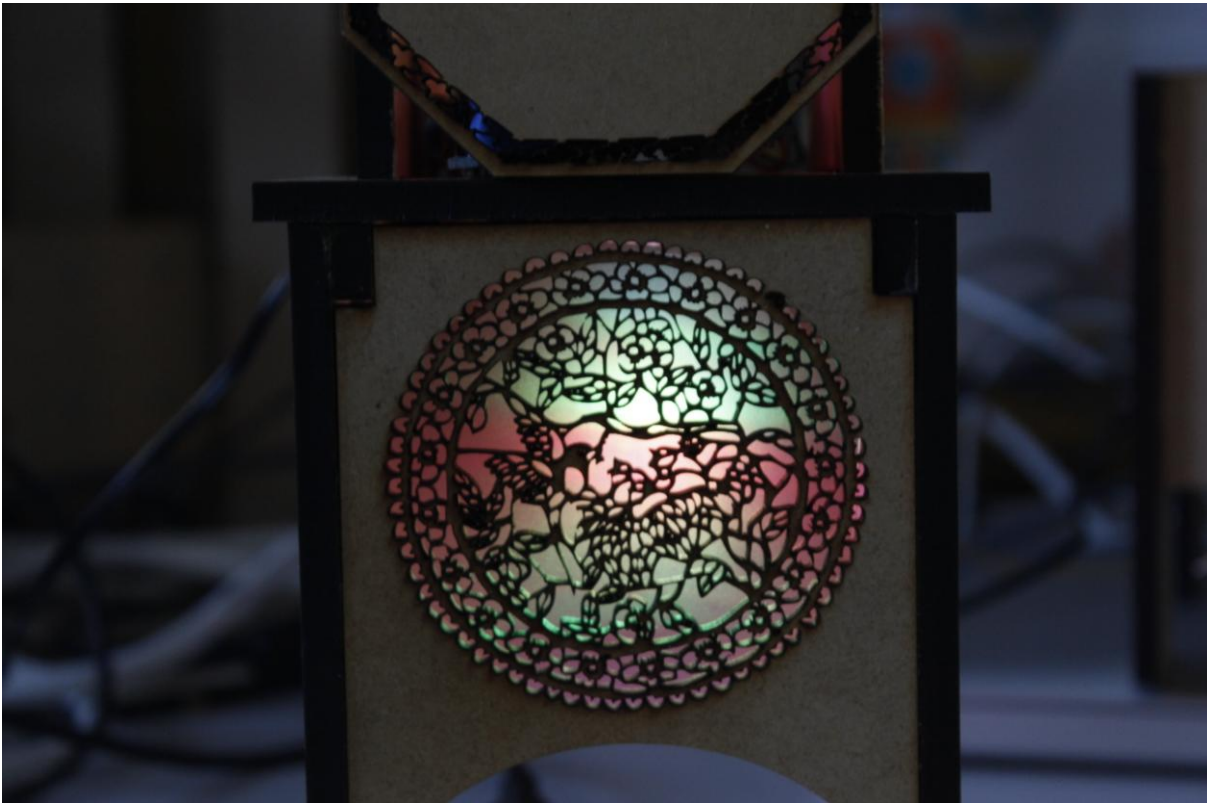


Figure 36 The visual design of *Experiential Converter V.1* adopted a style of Jianzhi

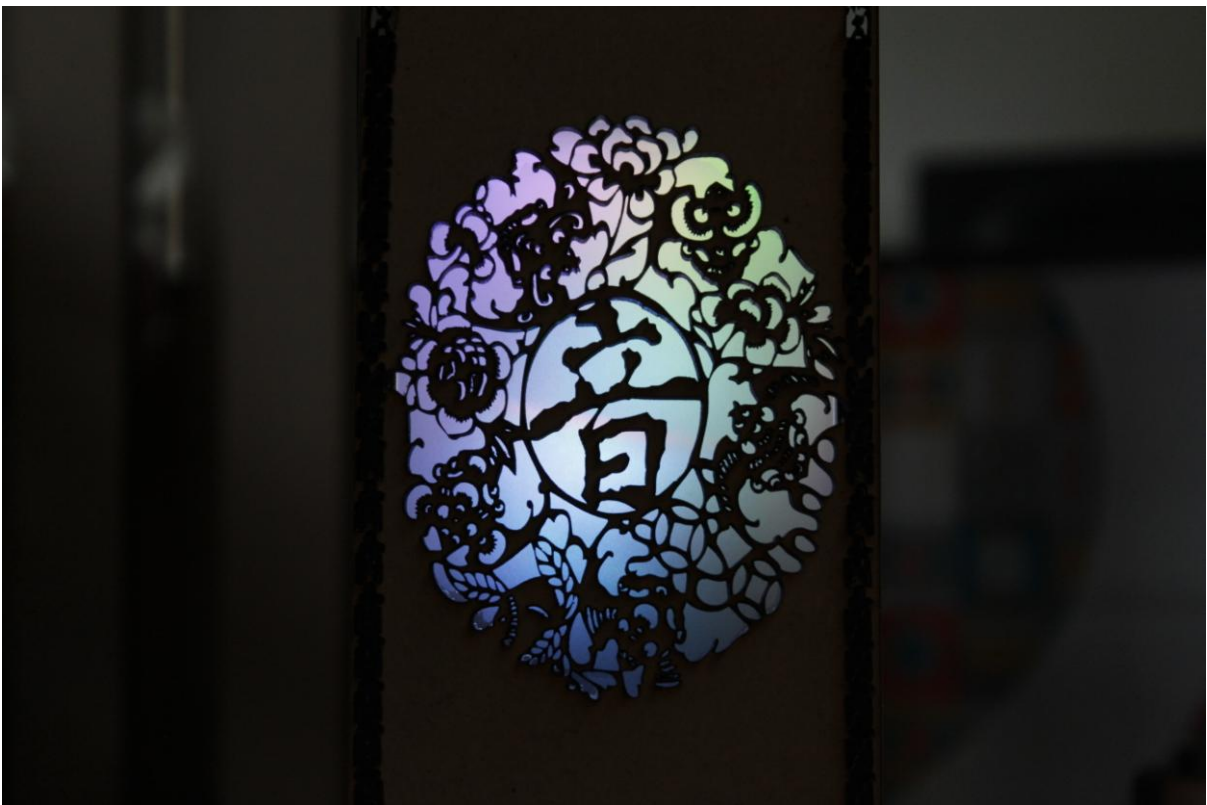


Figure 37 The visual design of *Experiential Converter V.1*. The Chinese character is 'Yin', meaning 'sound'

4.6.4 *General Technical Description*

Handcrafted with the help of fabrication technology, *Experiential Converter V.1* was assembled with multiple materials such as laser-cut cardboard, MDF, acrylic, tracing paper, LEDs, servomotors, *Arduino* boards and digital sensors. The technical development included four main parts: the *Processing* software that mapped an image into a colour wheel; the *Colour Collector* that measured the colour wheel; the sound generating software through *PureData*; and the *Motion Converter* that performed colour-light and motion. All the technical development was open sourced: supported by the online community and shared when finished.

4.6.4.1 *The Compositional Process: Mapping Image into a Colour Wheel*

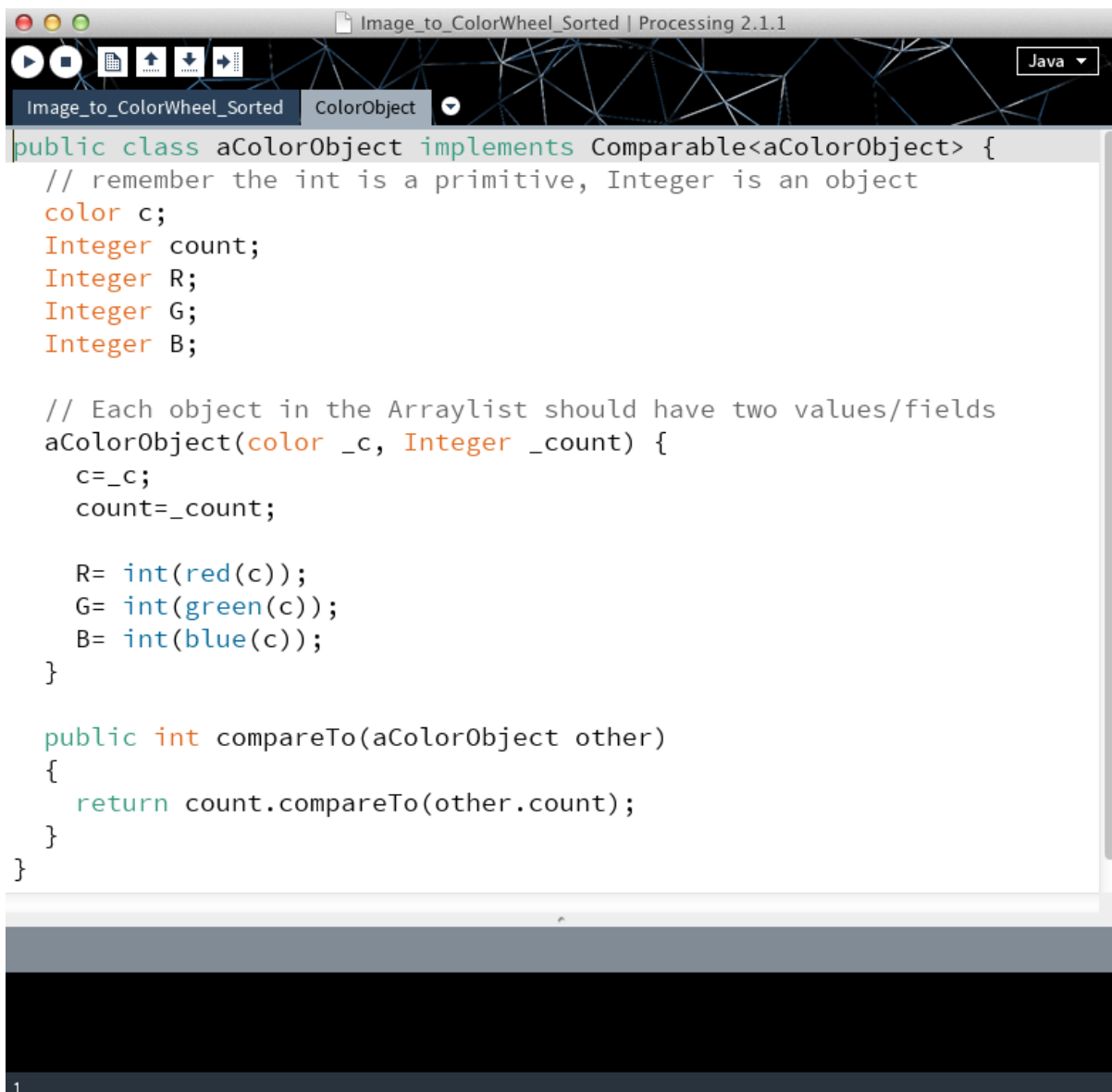
The first design was the software developed in *Processing* that calculated an image's colour information and mapped it into a colour wheel (Figure 38 and Figure 39). The colour information included the RGB values of each colour in a pixel and the frequency of this colour in the whole image. This software could map the colours in different ways: ascendant (or descendant) by the colour value (RGB), or by the hue, saturation and brightness value (HSB). Before the exhibition, various colour wheels were printed out onto card and laid on the table for the audience to play on the *Colour Collector*.

4.6.4.2 *Measuring the Colour Wheel: Colour Collector*

The second design was the *Colour Collector* that measured the information of the colour wheel (Figure 40). *Colour Collector* was a mechanism designed with an *Arduino* board, CdS photocell, 220-ohm resistor, RGB LED, breadboard, and a laser-cut MDF structure. It was mainly composed of a motor driving a turntable, a colour sensor and an LCD screen. It could detect and transfer colour information from the colour wheel and pass the information on to

two domains: the *Motion Converter* and the laptop.

A colour sensor was designed with an RGB LED and a photocell transistor. This design was based on the principle that colours absorb certain wavelengths and reflect certain wavelengths that the human eye perceives as different colours. Therefore, by progressively projecting red,

The image is a screenshot of the Processing 2.1.1 IDE. The title bar at the top reads 'Image_to_ColorWheel_Sorted | Processing 2.1.1'. Below the title bar is a toolbar with icons for play, stop, new, open, save, and zoom. The main window has two tabs: 'Image_to_ColorWheel_Sorted' and 'ColorObject'. The 'ColorObject' tab is active, displaying the following Java code:

```
public class aColorObject implements Comparable<aColorObject> {  
    // remember the int is a primitive, Integer is an object  
    color c;  
    Integer count;  
    Integer R;  
    Integer G;  
    Integer B;  
  
    // Each object in the ArrayList should have two values/fields  
    aColorObject(color _c, Integer _count) {  
        c=_c;  
        count=_count;  
  
        R= int(red(c));  
        G= int(green(c));  
        B= int(blue(c));  
    }  
  
    public int compareTo(aColorObject other)  
    {  
        return count.compareTo(other.count);  
    }  
}
```

The code is color-coded: keywords in blue, comments in grey, and variables/identifiers in orange. The background of the code editor has a dark, abstract geometric pattern. At the bottom of the IDE, there is a dark grey status bar with the number '1' on the left.

Figure 38 The *Processing* codes for the compositional process: calculating an image's colour information and mapping it into a colour wheel

green and blue light onto the surface and detecting the amount of wavelength that was reflected back using a photocell, the sensor could detect what colour the sensor was being exposed to. For more accurate readings, the circuit was delayed intentionally for one hundred milliseconds for the photocell to remain stable. The colour wheel turner was prototyped using a stepper motor, laser-cut MDF and acrylic. The *Arduino*-controlled stepper motor would slightly turn the wheel, wait for one hundred milliseconds in correspondence to the colour sensor, and slightly turn the wheel again for the next colour. Each colour on the wheel was detected progressively and saved into RGB format, for example:

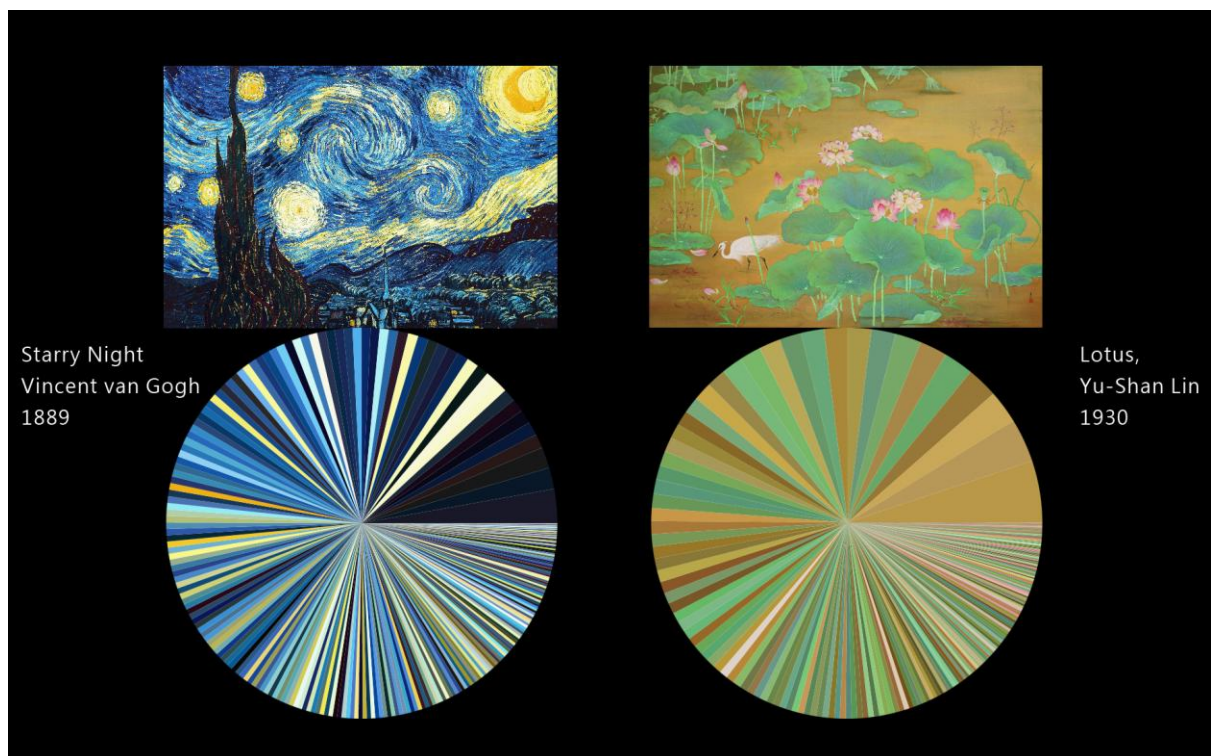


Figure 39 The mapping of *Starry Night* and *Lotus* into colour wheels

R = 232

G = 70

B = 0

was an orange colour.

Each colour's RGB value then was simultaneously transferred to two domains. The RGB value was sent simultaneously to the *Motion Converter* through I2C pins on *Arduino* boards to perform light and motion. Also, the RGB value was sent by Open Sound Control (OSC)⁶ to *PureData* tuning on a laptop to generate sound.

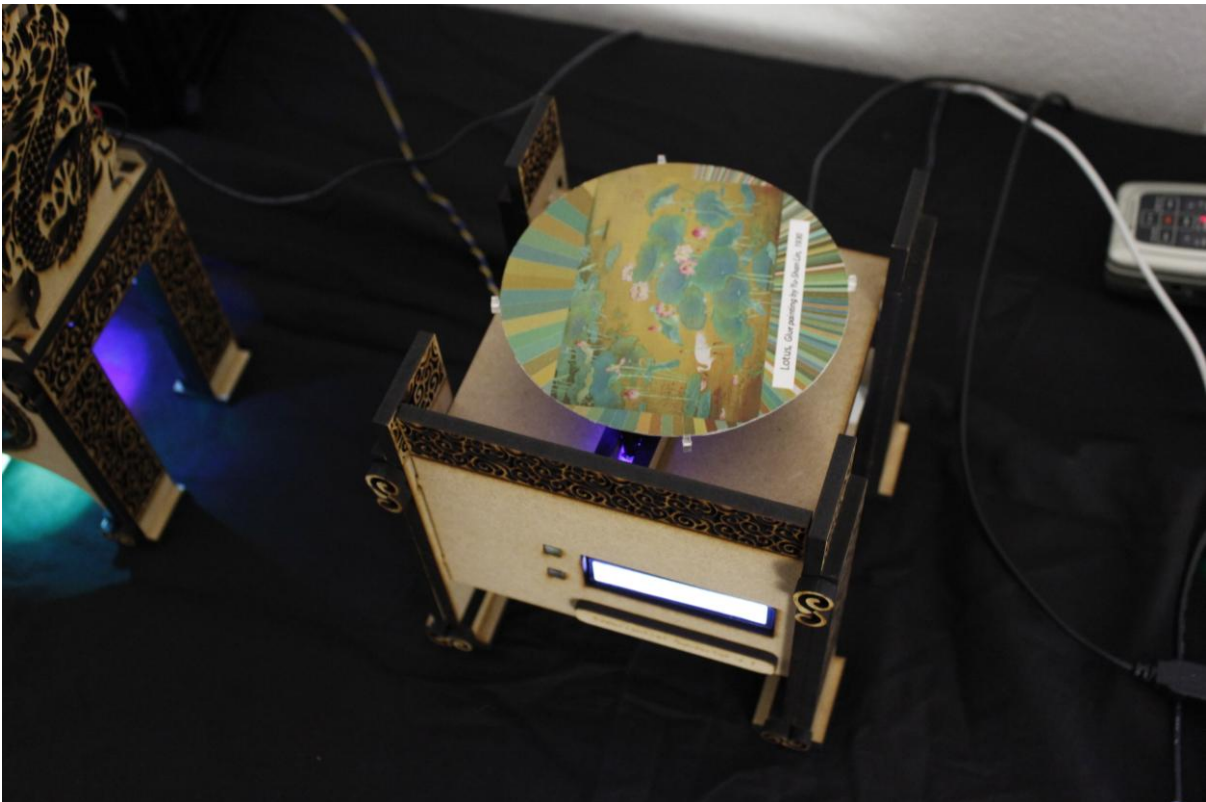


Figure 40 *The Colour Collector*

⁶ Open Sound Control (OSC) is a protocol for sharing music performance data between sound synthesizers, computers and other multimedia devices.

4.6.4.3 Generating Sound with PureData

In the *PureData* domain, the RGB values measured by *Colour Collector* were converted into three music tones through data mapping. That is, a chord of three notes (R, G and B) was used to represent each colour. Reflecting on the observational approach to Bishop's colour organ (reviewed in section 4.3.2), higher-pitch sound was applied to represent higher values. For example, a white colour (R=255, G=255, B=255) generated the highest pitch sound, while a black (R=0, G=0, B=0) generated the lowest pitch sound. The *PureData* patch was shown in (Figure 41). By listening to the whole colour wheel on the *Colour Collector*, an image was experienced as a melodic sound sequence. Taking the two images in Figure 39 as an example, Van Gogh's *Starry Night* generated a messy mixture of high and low pitch sound (for it has much colour contrast), while Yu-Shan Lin's *Lotus* produced more mid-tone sound (for it has relatively homogenous colour tones). A digital synthesizer *FM8* was applied to trigger different sound effects. The viewers could even try different effects if instructed.

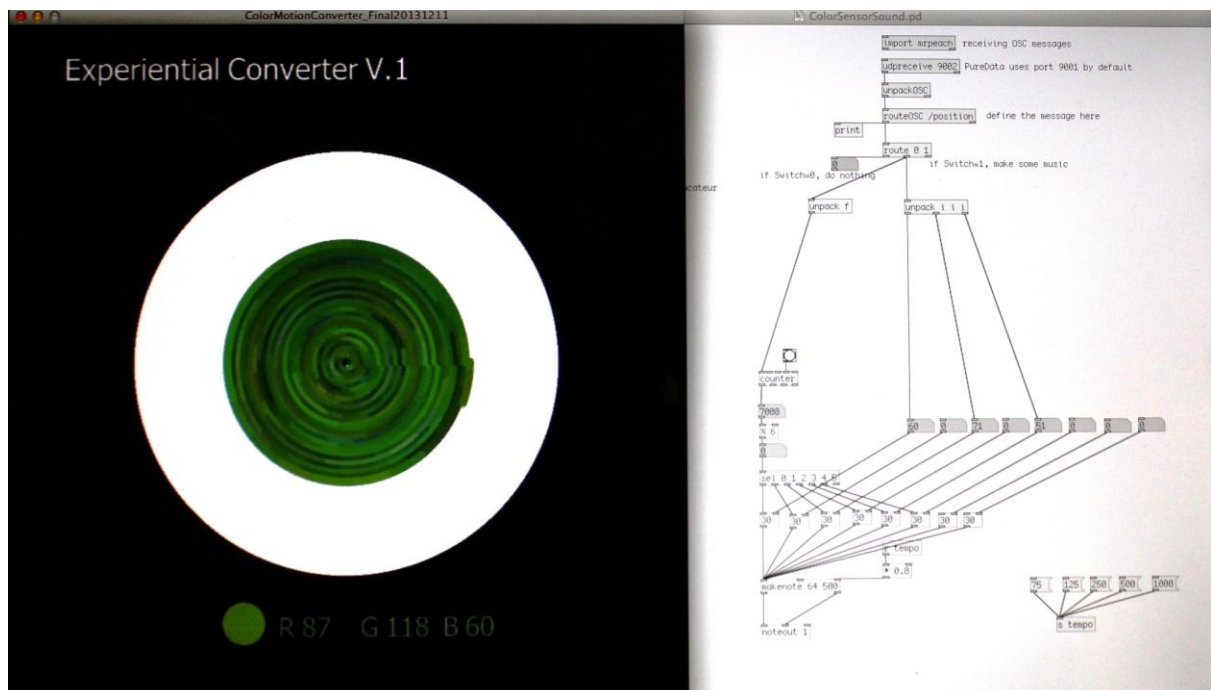


Figure 41 *PureData* patch and the visualisation of the performing colours

4.6.4.4 Performing Kinetic Colour-lights: Motion Converter

The *Motion Converter* was designed to convert colour (measured by *Colour Collector*) into a kinetic colour-light experience. Its visual design also possessed much detail by adopting a Jianzhi style (see Figure 42). Its mechanism was designed using three servomotors and several RGB LEDs. By mapping the R, G, B values into three angles between 0 – 180 degrees for the servomotors, each colour was represented by a unique position in space (Figure 43). Therefore, the higher contrast an image was, the more kinetic motion it generated. The hand-crafted LED lantern showed the colour-light the machine was processing at the time. Through the mechanism of *Motion Converter*, the audience could perceive an image by experiencing the spatial dynamics and co-occurrent coloured light corresponding to its melodic sound.

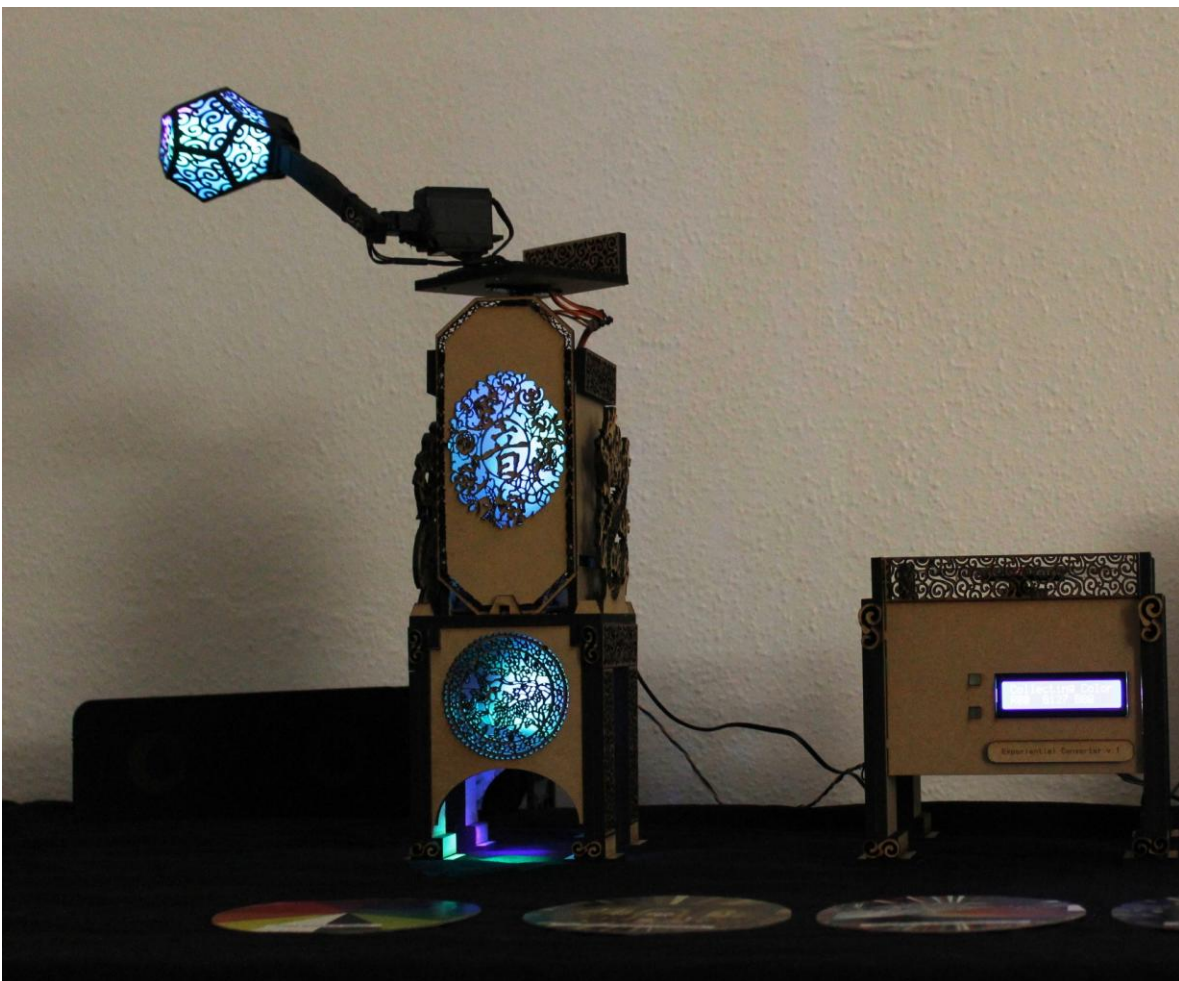


Figure 42 The *Motion Converter* was designed to convert colour into a kinetic colour-light experience

4.6.4.5 Visualising and Documenting the Performed Colours

Experiential Converter V.1 was designed as an installation that could be played by the participants. All the performed colours were visualized in real-time in the exhibition (Figure 44) and simultaneously saved as a file. The file could be later replayed or used for further experiment.

4.6.4.6 *Experiential Converter V.2 (as a Performance)*

Experiential Converter V.2 was developed for a live performance as part of *The Hypnopompic State*, a sound event held in Culture Lab, Newcastle University on 1st July 2014. In this performance, I worked in collaboration with Taiwanese assistant professor/musician Jennie Lin. In Aug 2014, a revised version of V.2 was also performed in *Unpitch_Action_4*, a sound event curated by Professor John Bowers, and musicians Ben Freeth and Tim Shaw.

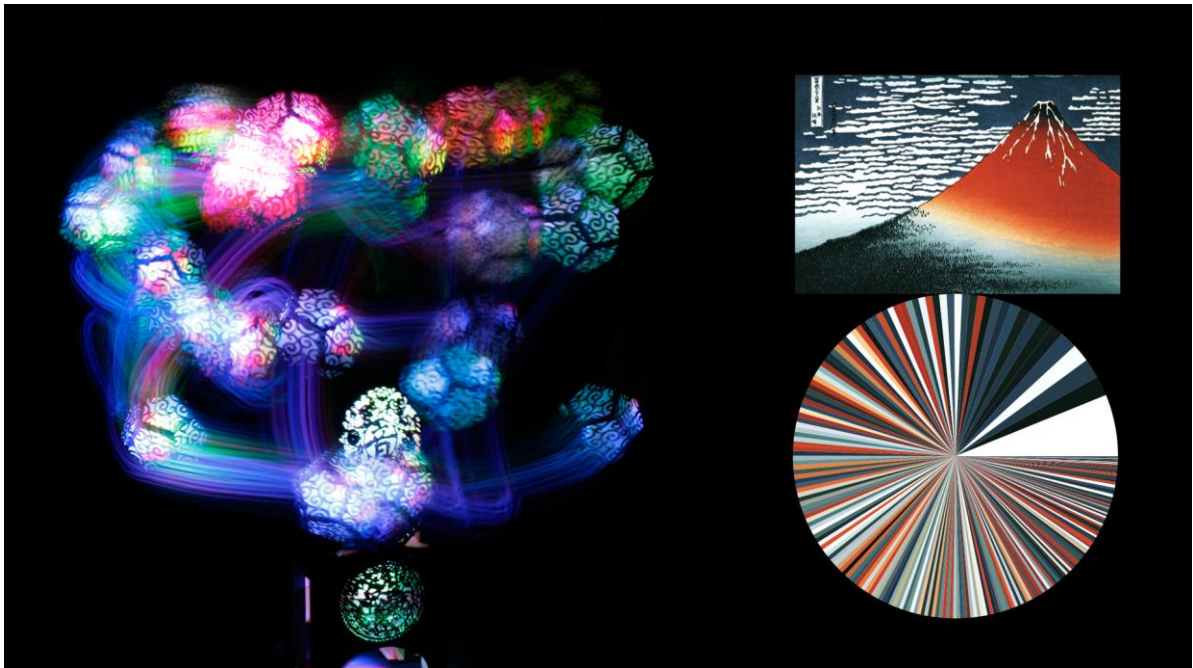


Figure 43 Correspondence between the colour wheel and dynamic light performance of an Ukiyoe woodprint. The left image as taken using long exposure photography

In *Experiential Converter V.2*, the *Colour Collector* (Figure 45) took the colour the performer was applying directly by hand and generated live sound. A pulse sensor was worn by the performer to trigger random sounds (i.e. rain drop, metal sound etc.). The sound changed the turning speed and light pattern of two kinetic-LED-sculptures every few seconds. Simultaneously, the performing colours were projected on the screen so the viewers could see the accumulated process of the performed colour-timeline in real-time (Figure 46).



Figure 44 The performed colours were drawn into a colour pattern on site and saved as a file that could later be revisited (see main text for explanation)

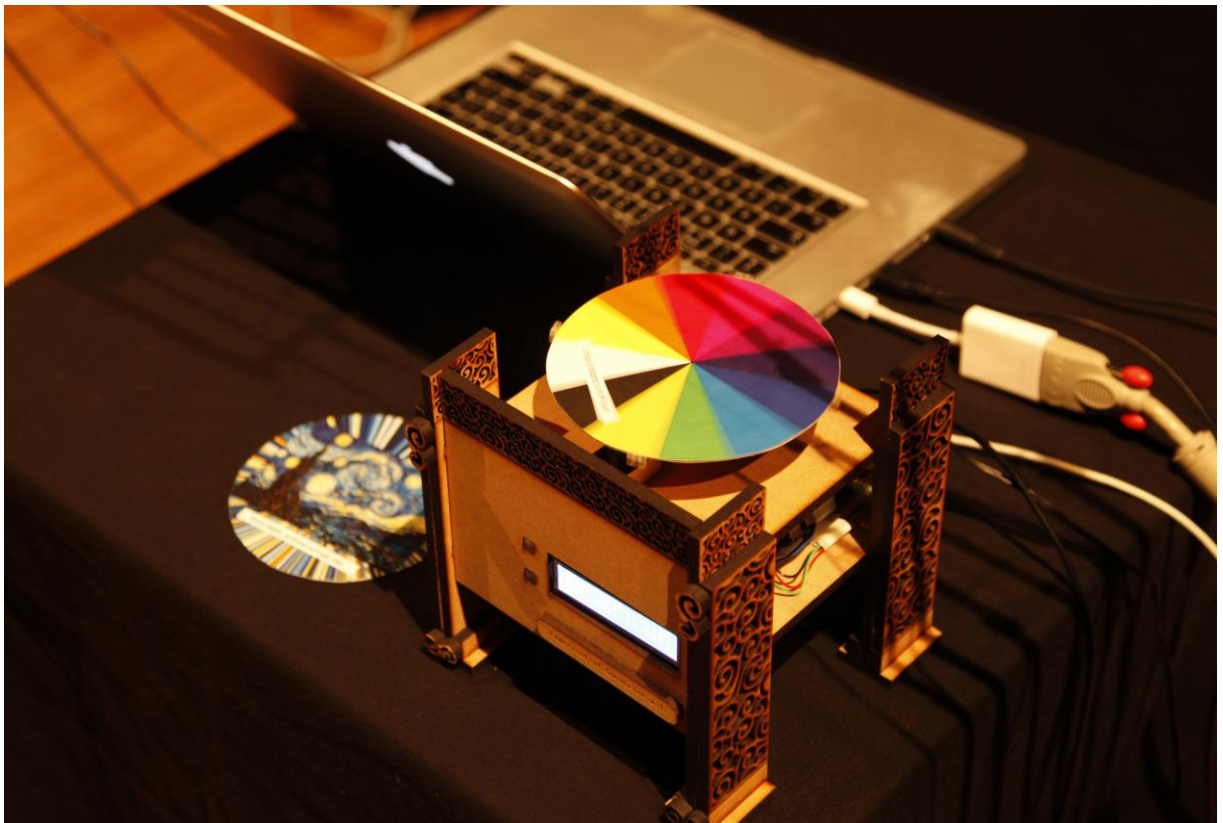


Figure 45 The *Colour Collector* in *Experiential Converter V.2*



Figure 46 The performance collaborated with Taiwanese assistant professor/musician Jennie Lin

4.6.5 *Technical Description: Dual Instrument for Co-occurrent Phenomena*

The analytic approach in the *Processing* sketch that converted an image to a colour wheel, the measuring mechanism of *Colour Collector*, and the practice of *Experiential Converter V.2* as a live performance engaged the unrealized dream of a ‘dual instrument for co-occurrent phenomena’ (section 4.4.1) through an ‘information-oriented’ (section 3.5.2) approach. Both designs incorporated a mechanism of analyzing and measuring colours but still allowed the users to interact with the device for an expressive experience. Through the audience’s engagement of *Experiential Converter V.1* and feedback of the performance of *Experiential Converter V.2*, both projects were considered to juxtapose the notion of composition/improvisation and created co-occurrent phenomena of sound, colour-light and motion that were generative and responsive. *Experiential Converter V.1* was also installed in a music-box-like setting, which referenced part of the canonical nature of Wundermaschinen. That is, the multiplicity of functions a mechanism can accomplish in a confined space (reviewed in section 3.3.2). This ‘performance-like setting for specific sensuousness’ (section 3.5.3) aimed to create social-interactions and encourage multiple viewers to play and listen in a compact space.

4.6.6 *Technical Description: Subtle Light Organ for Spiritual Resonance*

Both designs of *Experiential Converter V.1* and *V.2* materialized the notion of a ‘subtle light organ for spiritual resonance’ (discussed in section 4.4.2). As I have discussed earlier, Bishop was unable to create accurate correspondences for the subtle gradation of the sounds of nature. In order to tackle this unrealized dream, *Experiential Converter V.1* represented an RGB colour with three sound notes. The LED lantern on *Motion Converter* also performed colour-light subtly and accurately in different settings.

The performance of *Experiential Converter V.2* particularly aimed to tackle the unrealized dream of correspondence media for spiritual resonance through a spiritual-practice-like setting. A pulse sensor was worn by the performer to trigger sounds and create an ‘inner soundscape’. The stage light was turned down to encourage more resonant experience and meditation. The two kinetic-LED-sculptures were also transmitting regular motion lights to create a hypnotic atmosphere.

4.6.7 ***Technical Description: Apparatus for Communicating a Cross-modal Language in a Cross-cultural Setting***

In *Experiential Converter V.1*, the use of familiar art images to create generative and correspondent experiences is an attempt to communicate a cross-modal language between various cultures (section 4.4.3). For the *W.I.P* show in Culture Lab, four images from different cultures were used: Van Gogh’s *Starry Night* (1889), Yu-Shan Lin’s *Lotus* (1930), Raphael’s *School of Athens* (1509) and Katsushika Hokusai’s *Red Mt. Fuji, at dawn* (1830). These were converted into colour wheels for the audience to play in the exhibition.

Experiential Converter V.1 allowed the art images to be perceived correspondently and playfully in a cross-cultural setting. It performed a process of sensory abstraction in which all images became generative and dynamic through sound and kinetic performance. While the computational mechanism converted the colours into sound and motion by mathematical means, the audience’s experience was a perception of a cross-modal language that could be shared across cultural and language backgrounds.

4.6.8 *Audience Response and Self-reflection*

4.6.8.1 *Audience Response*

Experiential Converter V.1 was exhibited in the *W.I.P.* show in Space 7, Culture Lab, Newcastle University in December 2013. It was also described in an article in *Digital Art Critique. No. 5*, a periodical published in Taipei, Taiwan in 2016 (Li, 2016). Some audience response to observing the work was collected.

In the *W.I.P.* show, most audiences considered *Experiential Converter V.1* a novel piece to turn an image into sequence of sound in a music-box-like setting. Many viewers showed particular interest in what specific images (e.g. Van Gogh's *Starry Night*) sounded like. Some audiences compared two sequences of sound together and tried to find similarities/differences between two images. Some mentioned that *Experiential Converter V.1* diverged from other experiences created by computational means, since the colour wheel rotated very slowly, making it similar to historical technology. Some mentioned that *Experiential Converter V.1* provided an alternative setting for experiencing historical artworks, and a potential link between images from different cultures. The audiences generally were encouraged to play with, discuss, and explore the correspondence experience of colour-sound-motion. Many expressed their curiosity about *Experiential Converter V.1*'s technical details. One of the audience member said she liked the Jianzhi-style lantern design of *Experiential Converter V.1*. and the re-engagement of images from different cultures, she said this can generate many "cross-cultural" discussions.

In *The Hypnopompic State*, *Experiential Converter V.2* gained multiple audience response. The work's intention to create a live correspondence (between colour, sound and motion) as a method to transcend human senses and develop human spirit was explained to the audience before the performance. The performance was later discussed with some audience members

after the event. Some thought the work was intriguing as it communicated what I proposed. However, some thought the idea of ‘spiritual communication’ was slightly vague and not easily perceived.

4.6.8.2 *Self-reflection*

Reflecting the preceding review of unrealized dreams of correspondence media (in section 4.4), *Experiential Converter* was considered a media artefact that “mediates impossible desires” (Kluitenberg, 2011, p.66). That is, the aberrant trajectories of dual instrument for co-occurrent phenomena, subtle light organ for spiritual resonance, and apparatus for communicating a cross-modal language in a cross-cultural setting. The esoteric notion of correspondence was tackled through a computational process. *Experiential Converter V.1* and *V.2* could thus be considered Wundermaschinen that tackle the techno-historical unrealized dreams. However, among the three dreams, I was concerned with the notion of spiritual resonance as the vaguest conceptualization in this exploration. The design of *Experiential Converter* somehow made it unable to communicate such tendency. It was this inquiry that motivated another thread of practices in this research (which will be explored in Chapter 5).

4.6.9 ***Implications: Dual Instrument of Live Information Transformation***

Through a computational process of measuring, calculating, and signal processing, the practice of *Experiential Converter* reflected an emerging way of understanding the world. As architect/composer Marcos Novak suggests:

“We live in a time of scientific visualisation, and, increasingly, sonification, where we find that other, neglected, sensory pathways allow us to understand this world more fully and immediately than the conventional, numerical, calculated way we have inherited.” (Novak, 2007)

Reflecting Novak's notion, the concept of *Experiential Converter* could be extended to various kinds of live information transformation (e.g. turning a historical space into a visual-musical experience or an object's formation into a sequence of sound). However, differently from Novak, what directed this piece was more cultural and esoteric than scientific. A Wundermaschine of correspondence has its cultural-historical relation to esotericism, where natural elements were regarded as transformable. It also reflects on the hybrid identity of engineer, psychic and magician (in section 2.3.6) with which the world is observed as a dynamic system of microcosm and macrocosm. The relationship between entities can be creatively revealed through artefact design, and in doing so, convey or enrich our understanding of such world.

In other words, the experiment of *Experiential Converter* by means of information visualisation, sonification, and computational composition does not limit itself to the world that is, but can proceed to examine the world of 'transcendence'. By 'transcendence', as I have discussed in Li (2015b), I mean that practitioners can envision an instrument that peers into potential worlds and that returns not simply images, lights or sounds, but complex compositions for all our sensual, emotional and intellectual capacities. Such an artefact embodies two characters. The first character is 'expressive', the function familiar to a performer. This instrument has sensual, emotional and intellectual levers, operating at many levels simultaneously. It extends the expressive domain of an individual, achieved by an apparatus that allows a high degree of control over some aspect of the sensory world. The other character is 'analytic', one that allows us to peer into worlds beyond our normal senses to bring together patterns beyond our normal recognition, and in so doing, enrich the world we live in. The second character maps aspects of the world that are outside our range or scale (e.g. the accurate composition of colours of an image or object) into regions within our sensorium, and within our perceptual, cognitive and affective ranges (sound and kinetic

motion). *Experiential Converter* has demonstrated that this dual character can be achieved, can be played or performed creatively, and what is returned is as much expressive of a complete human presence as any instrument.

Such notions of ‘world-reconfiguration’ through *Experiential Converter* could also be acknowledged by Karen Barad (2003) as ‘performative’. Barad suggests there are no inherently bounded and propertied things that precede their intra-action with particular apparatuses. She suggests “matter is substance in its iterative intra-active becoming – not a thing, but a doing, a congealing of agency.” (Kleinman, 2012, p.80). It is only in, and through, intra-action that boundaries and properties of “thing-in-phenomena” (Kleinman, 2012, p.80) materialize. For Barad, apparatuses like *Experiential Converter* are not just inscription devices or scientific instruments set in place before the action happens, or machines that mediate the dialectic of resistance and accommodation. The instruments are themselves phenomena:

“Apparatuses are not mere static arrangements in the world, but rather apparatuses are dynamic (re)configurings of the world, specific agential practices/intra-actions/performances through which specific exclusionary boundaries are enacted.” (Barad, 2003, p.816)

In Barad’s words, it is the various human-machine intra-action that allows us to enrich the discussion, and redefine the boundary, between attributes of human and machines.

Experiential Converter should thus be considered an apparatus of “entanglement” (Kleinman, 2012, p.77). That is, it reveals how the colours of an art image can be entangled with the tones of sound in spaces and times. The presumed boundaries and properties of visual and auditory distinction are reconfigured and re-determined. Through *Experiential Converter*, particular material articulations of our universe become meaningful.

4.6.10 *Implications: Media Archaeology as Artistic Methodology*

In this chapter, I have adopted a media archaeological approach in my research. The unrealized dreams of correspondence media were excavated and engaged in a contemporary design process. This approach of media archaeology is particularly significant as it reflects on, and provides practical examples for, a ‘media archaeology as artistic methodology’ (Hertz & Parikka, 2012). It shows that media archaeology can clearly articulate its relation to art and design practice. It suggests how the aspects of wonder of emerging computer-assisted fabrication can be reformulated through an archaeological orientation.

In addition, *Experiential Converter V.I*’s conversion of historical art images through technical means reflects on Wolfgang Ernst’s version of media archaeology:

“The term media archaeology, describes modes of writing that are not human textual products but rather expressions of the machines themselves, functions of their very mediatic logic.” (Ernst, 2011, p.242)

For Ernst (2011), media should be primarily researched as non-signifying channels. The fact of ‘mediation’ should be considered before any idea of hermeneutic meaning. ‘Mediation’ refers to what media do, and to what we do with the media. It is the term that defines the media as actively creating a symbolic and culture space (Silverston, 2006).

Ernst contends that the phenomenological content of communication is too often mistaken for the essence of media, and media archaeology should focus on the agency of the machine: the ways in which technical media themselves contract time and space. In this sense, the ‘objective pastness’ (Ernst, 2005) and ‘reverse-remediations’ (Gansing, 2011) achieved by *Experiential Converter V.I* are contributive. It processed what actually happened in the past (the mathematical relations between colours of an art image) and intended to neutralize the

subjective stance of the art historian. That is, a more radical approach to the artworks: not on the images by painters, but rather on the non-discursive elements of colours of images.

In other words, *Experiential Converter* allowed the audiences to listen un-interpretively to the artist's original arrangement of colours, through their complexity. For Ernst, *Experiential Converter* can be considered an "active archaeologist machine" (Ernst, 2011, p.242) that reconstructs a lost (or ignored) signal inaccessible to human senses: the correspondence experience that can be generated by analysing historical art images. The making of *Experiential Converter* could be seen as an epistemological reverse engineering: "an awareness of moments when media themselves, not exclusively humans anymore, become active archaeologists of knowledge" (Ernst, 2011, p.239). The practice of such Wundermaschine is thus at the same time creative and media archaeological.

4.6.11 *New Knowledge Occurred in the Making*

The making of *Experiential Converter* revealed a few potentials and challenges. Firstly, the mapping of massive colour information of an image onto a small colour wheel was proven a challenge in design. In the future, how to map rich information onto a physical surface without losing its quantity and accuracy will be worth exploring. It is also suggested that the maker/artist works with museums to gain more reliable image formats for analysis. The next version of *Experiential Converter* will slow down the whole technical process of colour-sound conversion. This is because it may prevent the mechanism from making mistakes. This may also provoke potential discussion on 'slow computing' (further explored in section 5.6.6.1). Please see Appendix 13 for more details.

4.7 Future Developments

Through research into media archaeology, this chapter shows a developmental process toward ‘Wundermaschinen of Correspondence’ and articulates their implications in the context of media history and future technological developments. The Wundermaschine of correspondence is a dual instrument (section 4.6.9) of the expressive and scientific, a machinery of curiosity (section 3.5.6) about the unrealized dreams of correspondence media, an artefact of refined labour (section 3.5.1), which is presented in a performance-like setting (section 3.5.3). It engages audiences with critical cultural-historical implications in the integration of science, art and engineering through emerging computer-assisted making. In addition, the practices of *Samsare Eye* and *Experiential Converter* in this chapter suggest a more specific approach to making contemporary Wundermaschinen: that is, a media-archaeology driven practice utilizing computational technology. The practice of *Experiential Converter* established that the unrealized dreams (section 1.5.2) of media could be embraced as a developmental context with specific technical goals and design aesthetics for contemporary Wundermaschinen. This application of media archaeology as artistic methodology will be further developed in Chapter 5.

In addition, from the perspective of the media practitioner, the practices in this chapter also located one risk of such a methodology. That is, a media archaeology driven Wundermaschine design could obviously be a machine that creatively tackles the techno-historical dreams, but how can such a machine talk to, or be mutually informed by, other present artefacts? This question emerged since the research found that where present practice could tackle the techno-historical dreams it was inevitably bound by the characteristics of present technology (such as how *Kinect* created a space of embodiment in *Samsare Eye* and how electronic gadgets created occurrent signal processing in *Experiential Converter*). The rich possibilities of constructing contemporary Wundermaschine through excavation of historical dreams

should not exclude the abundant information that could be provided by contemporary artefact analysis.

Therefore, in Chapter 5, this research will continue into media archaeology driven practice. However, the way it excavates the unrealized dreams will be slightly different from Chapter 4. It will review the multiple metaphors and imageries of a specific technology (the clock), and by critically comparing them to more recent artefacts constructed by artists, will excavate further potential for designing contemporary Wundermaschinen.

Chapter 5 Developing Wundermaschinen of Revelation

5.1 Introduction

In Chapter 3, I discussed the family resemblances of ‘machinery of curiosity’ (section 3.5.6) and ‘object of philosophical argument’ (section 3.5.7) amongst canonical Wundermaschinen. I have also contended that the Wundermaschine is an appropriate media form, expression or framework of prototyping for the artist to state a critical argument, especially towards a fundamental philosophical concern. In Chapter 4, I considered technology for ‘spiritual resonance’ as one critical unrealized/forgotten dream of human technology (section 4.4.2). However, the design and setting of *Experiential Converter* (section 4.6) seemed less convincing for communicating such notions to the audience. Therefore, the exploration in preceding chapters raised one specific inquiry: How could we further explore this spiritual resonance with an alternative media form?

In this chapter, I continue to explore such an unrealized notion of harmony between technology and the human soul through experimental practices toward a ‘Wundermaschine of revelation’. By revelation, this research particularly reflects on the historical notion of divine communication in clockwork in later Middle Age Europe (which will be reviewed in section 5.3.1) and considers technology as one evolutionary step in the unfolding of mankind’s higher levels of consciousness.

In summary, section 5.2 will describe an experimental project *TimeFlower* (Feb – Aug 2013), which aimed to reveal the richness of time. Reflections on this project led toward more focused concerns and implementations of a more physical and atmospheric design mechanism. Section 5.3 will revisit various clock metaphors in the cultural history of technology with the

specific intention of locating unrealized or forgotten dreams. Reflecting the concerns in section 4.7, I critically compare these dreams to contemporary creative artefacts to clarify two ‘unrealized’ facets of wonder in section 5.4. This contextual review will be reflected in section 5.6 in the annotation of a practical experiment into creating a ‘Wundermaschine of Revelation’ – *Botanical Universe* (Apr – Dec 2014).

5.2 Experimental Project – TimeFlower (Feb – Aug 2013)

5.2.1 *Methodology*

Influenced by the formation of clockwork automata, the making of *TimeFlower* was to explore how the clockwork could be transformed to embody more characteristics of the digital, such as being more responsive and information-oriented, to engender wonder in the audience. *Processing* was utilized to design a dynamic visualisation (see section 5.2.4 for technical detail). Different versions of *TimeFlower* were displayed in shows and seminars for feedback and reflection (section 5.2.5). Based on the feedback and reflection, implications of this practice will be given in section 5.2.6. The practice of *TimeFlower* led this research to explore another thread of Wundermaschinen making, that is, the Wundermaschinen of Revelation.

5.2.2 *Aims and Developmental Context*

Reflecting on a continued interest in correspondence (as discussed in Chapter 4) and a review of the canonical clockwork Wundermaschine (as outlined in section 3.3.2), *TimeFlower* (see Figure 47 and Appendix 6) was conducted and exhibited as a media art experiment in February – August 2013. It attempted to explore the relationship between time representation and wonder by following a framework for 21st century Wundermaschine (speculated in section 3.5). It specifically aimed to materialize the characteristics of ‘metaphorical’ (section 3.3.2) and ‘information oriented visual complexity’ (section 3.5.2). It was also developed as a

wondrous form of clock that embodied the characteristics of ‘occurrent processing’ (section 3.5.6). The motivation of the practice was to investigate how we could reveal the richness of time, and, how the framework of the 21st century Wundermaschine could be applied to modify the common form of a clock.

5.2.3 *Design, Implementation and Aesthetics*

Reflecting the emerging identity of ‘media practitioner as engineer-psychic-magician’ (discussed in section 2.4), it was the ancient esoteric perspective of correspondence between microcosm and macrocosm that informed the practice of *TimeFlower*. For example, the esoteric Wu Xing (Five Phases) Theory in historical Chinese philosophy suggests that there is a correspondence between the cosmic cycles and the interaction between human internal organs. The universe is considered a dynamic mechanism that is itself a phenomenon of transformation and change, and the life of humankind is itself a search for harmonious interaction in such transformation. *TimeFlower* was designed to inquire: how could we embody such an idea of transformation in the design of a timekeeper? Could we design a timekeeper that simultaneously ticks accurately and performs like a metaphorical kaleidoscope showing a unique colour for every moment?

5.2.4 *Technical Description*

5.2.4.1 *Visual Design in Illustrator and Processing*

TimeFlower was designed as a time-mechanism that showed corresponding colours and forms for each second through image projection. The hour, minute and second readings of time were translated into values for hue, saturation and brightness (HSB) respectively using simple algorithms that calculated and mapped the digits. For example, I made the colour of a layer time-responsive by using the following code in *Processing*:

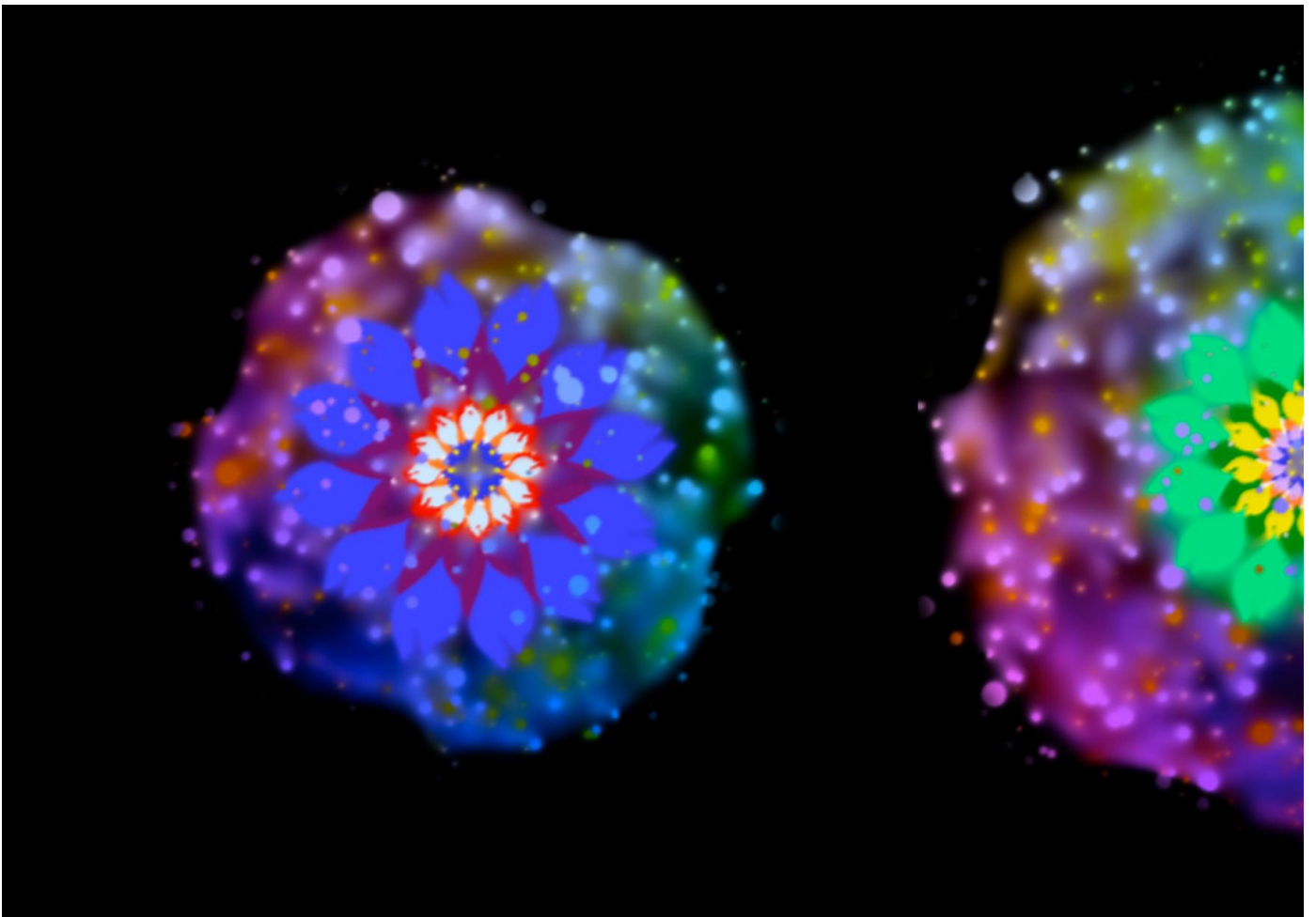
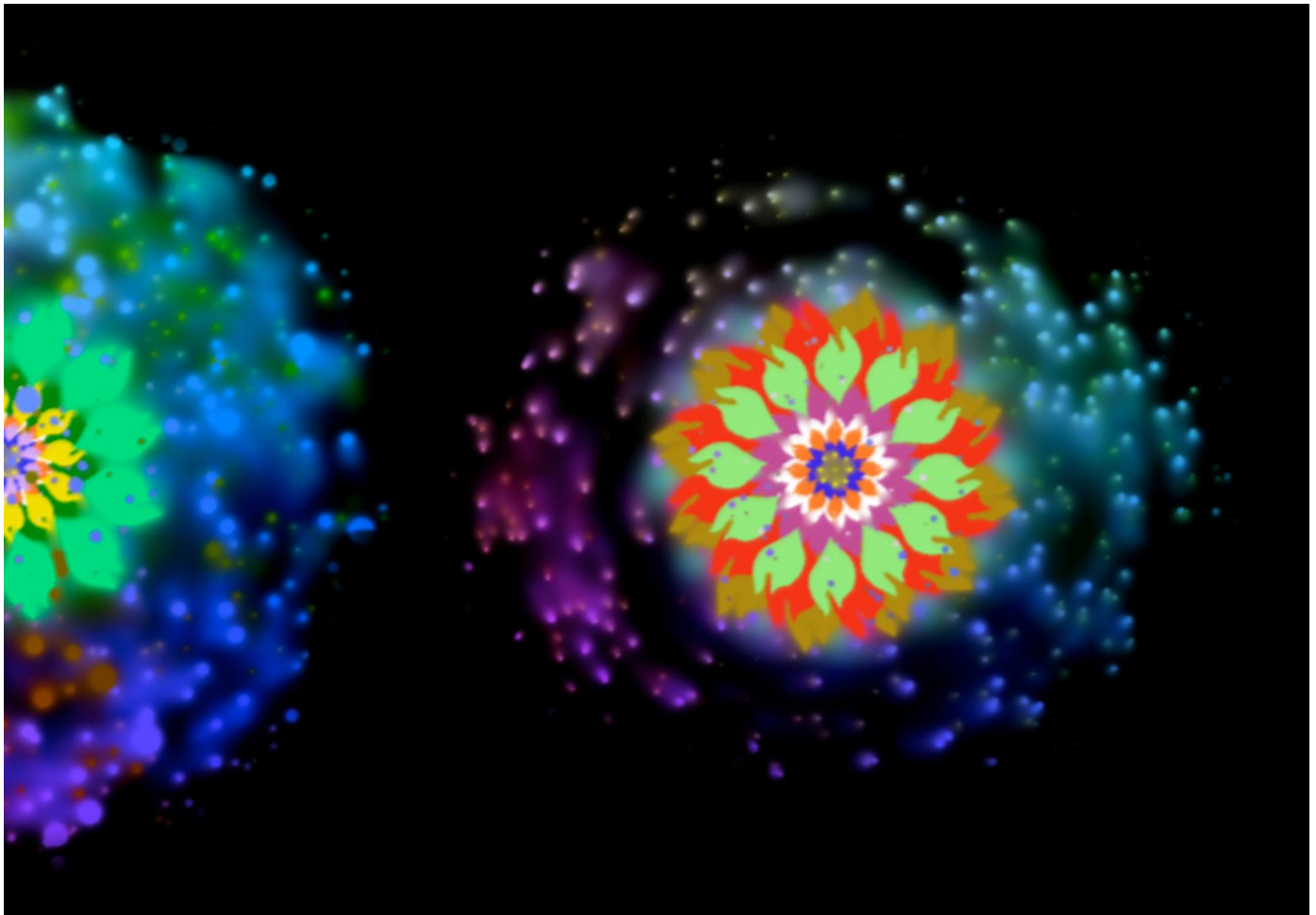


Figure 47 Visualisation of *TimeFlower*



```

“// map the hour digits (between 0 - 24) into colour hue:
int Hue = map (hour, 0, 24, 0, 255);
// map the minute digits (between 0 - 60) into colour saturation:
int Saturation = map (minute, 0, 60, 0, 255);
// map the second digits (between 0 - 60) into colour brightness:
int Brightness = map (second, 0, 60, 0, 255);
// assign the HSB colour to a specific layer of TimeFlower:
color LayerOne = (Hue, Saturation, Brightness); “

```

Functioning with the above *Processing* codes, *TimeFlower* had a repeatable 24-hour pattern and exactly the same pattern was visible at the same time each day. In other words, for each moment, there was a unique visual representation (see Figure 48 and Figure 49). The abstraction of time into a rotating and transforming flower reflected Chinese Taoist ethics that emphasized the action of non-action by following naturalness (Wang, 1989, p.5) and the truth in simplicity and wholeness (Kohn & LaFargue, 1998, pp.111, 170). It also followed the Taoist preference of using natural elements, metaphors or relations to explain philosophies of life. For example, the animation design of *TimeFlower* reflected on the Taoist metaphor Yin-Yang, suggesting dynamic formation and mutual restriction and interaction. The petal shapes were drawn in *Illustrator* using the Pen Tool. The shapes could then be duplicated into

5.2.4.2 Import the Petals Image into Processing

The .svg file was then imported into *Processing* using the *loadShape* function. With this technique, each of the petal formations could be given a new and separate colour and size for any time frame.

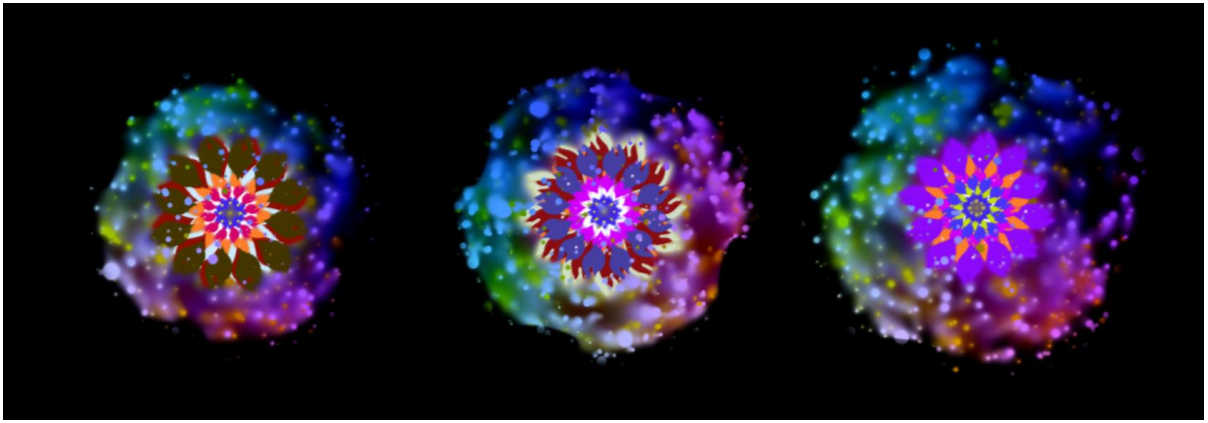


Figure 48 The representation of 10:07:12

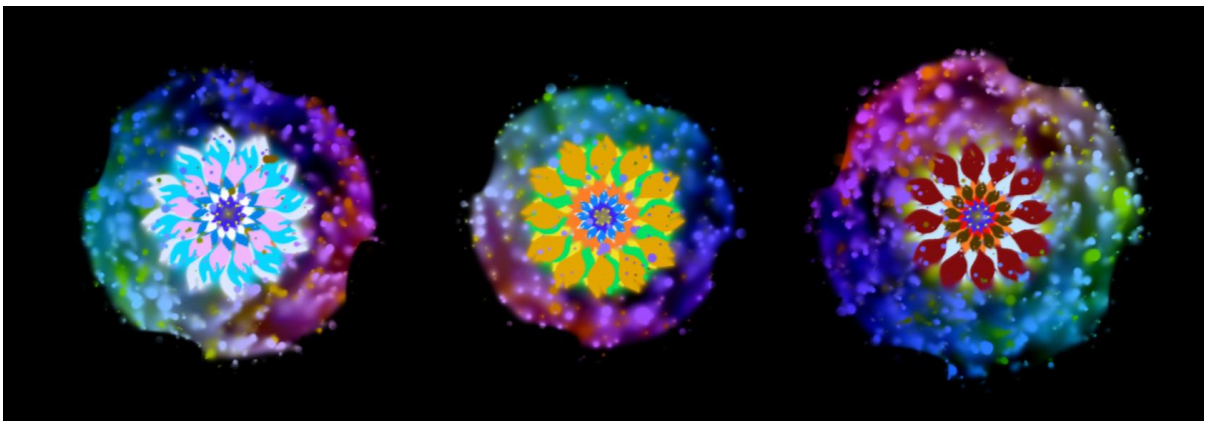


Figure 49 The representation of 10:09:52

a radial balance formation. The formation was exported as .svg files for later use in *Processing*.

5.2.4.3 *Animation Design for Occurrent and Metaphorical Quality*

In Chinese Taoism, Wu Xing's Five Phases Theory is primarily concerned with process and change. The common translation as phases or agents instead of elements also indicates the concept of "mutual generation" (Deng, Zhu & Xu, 2000) between different entities. Therefore, stillness and slow motion, two primary means of Taoist meditation were adopted in *TimeFlower*'s animation design. *TimeFlower* was set to animate every two seconds: one second in stillness and another in motion and change.

The visualisation had two main parts: the rotating particles in the background and the transforming layers of flower petals. The background of each flower rotated 1/120 degrees every two seconds (360 degrees as separated by 86400 seconds per day, giving 43200 movements). All the particles in the background randomly moved around and changed size. However, their colours remained in correspondence with their position on the screen. The particles appeared clear while moving and blurred when still. The flower had eight petal layers that slowly moved forwards and back at z depth, while rotating in different speeds and directions. The front petals overlapped the ones in the back. It was this visualisation that gave *TimeFlower* more ‘visual complexity’ (section 3.5.2) and demonstrated a certain quality of ‘occurrent processing’ (section 3.5.6).

5.2.4.4 *Blur Colours for more Spiritual Implication*

With the intention to reveal the rich dimensions and metaphors of time, the complexity of colour was considered important in the abstracted form of visualisation. Some of the colours were generative (by randomly incrementing the H, S, and B values) and others correspondent (by keeping a mathematical relation with the hour, minute and second readings). This was to create a rich complexity in colour and transformation, yet not to be noisy and distracting. Through experiments and feedback, I found strident and jarring colours kept the audience from observing the details, such as the gradation between colours and the overlapping layers of flower petals.

Therefore, to prevent the audience becoming distracted by over-contrasting colour and formation, I developed a blur effect (Figure 51) through *Processing* code. The main idea was to create an aura effect by averaging each pixel with its adjacent one in each frame. The difference between the blurred effects and normal visualisation can be clearly seen in (Figure

50). To present a clearer understanding of the gap between each second, the sound of a tick was also triggered every two seconds while the image started motion.

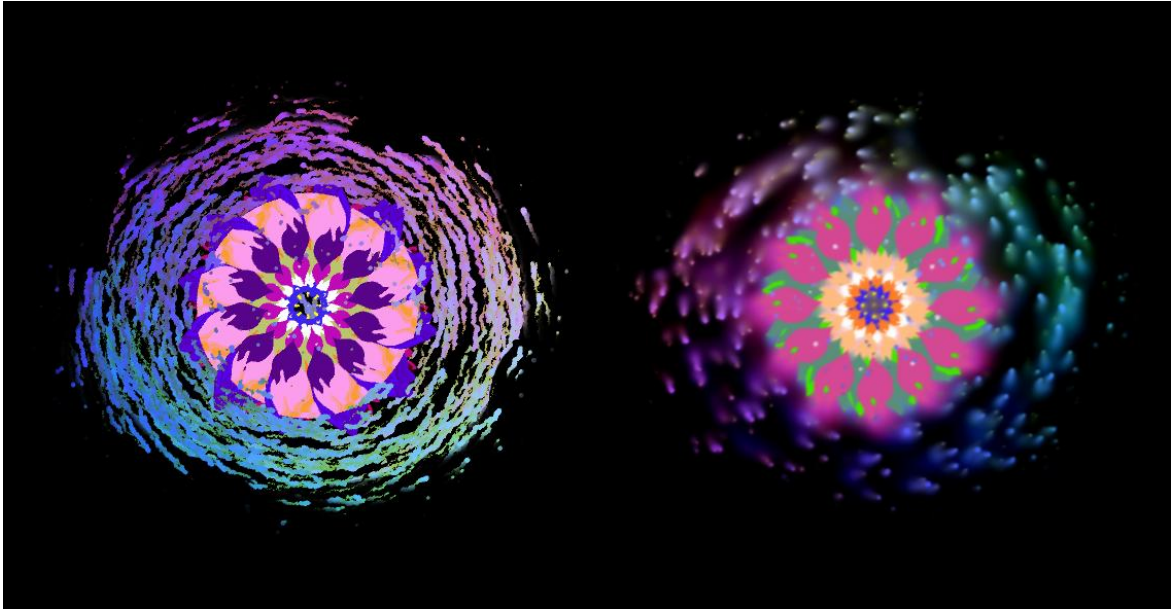


Figure 50 The un-blurred (left) and blurred effects (right)

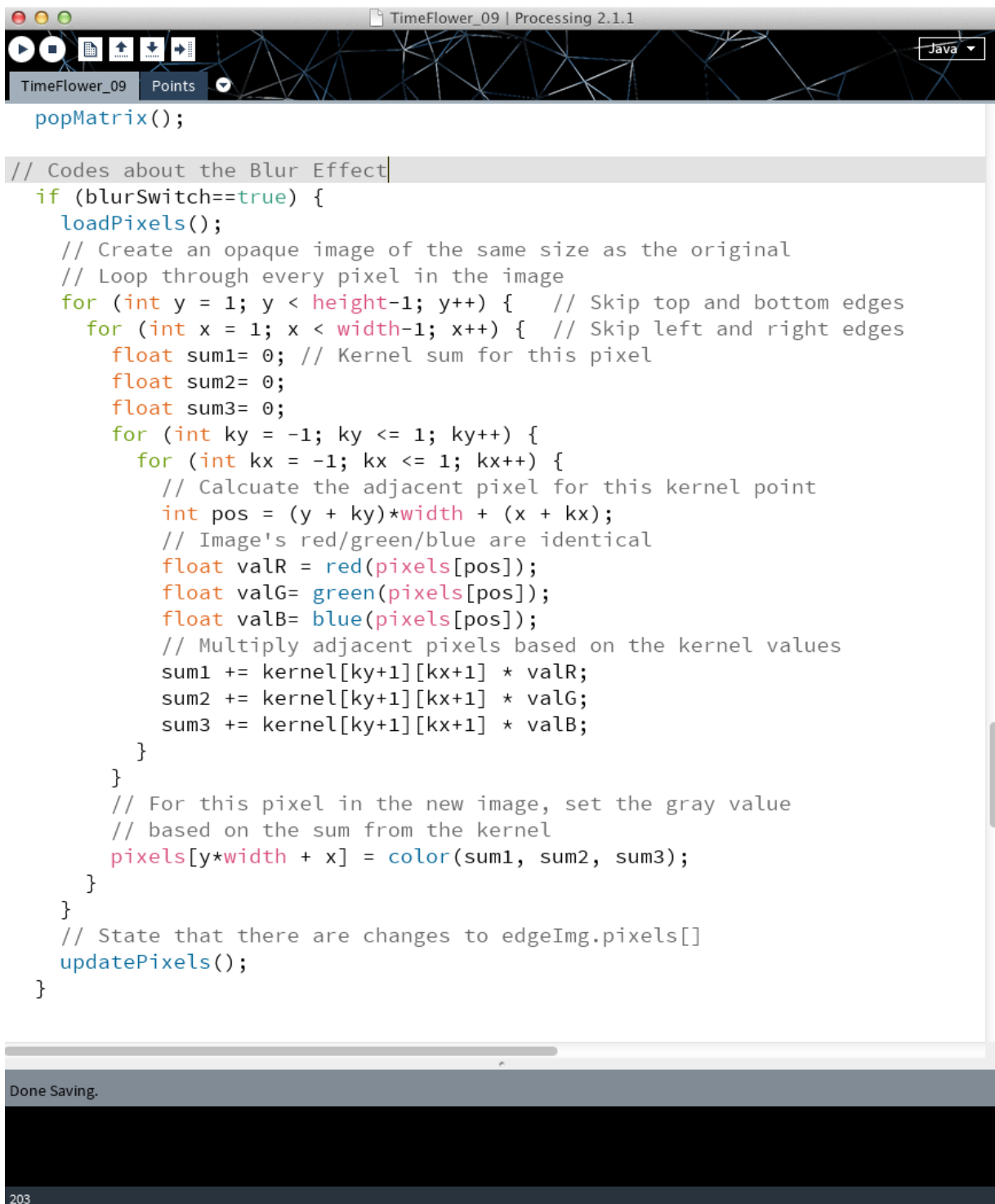


Figure 51 Screenshot of *Processing* codes for creating blur effect in *TimeFlower*

5.2.5 *Audience Response and Self-reflection*

5.2.5.1 *Audience Response*

TimeFlower was presented in a *Digital Media Seminar* in Culture Lab, Newcastle University in 22 Jan 2014, and a workshop in Da-Jhen University in Ping-Tung, Taiwan in Jan 2015.

In the *Digital Media Seminar*, most of the seminar participants and audience were intrigued by how familiar systems of representing time could be questioned and disrupted in *TimeFlower*. Most of them silently observed the work in detail for several seconds, even minutes, indicating positive feedback for my intention of creating wonder. In Da-Jhen University, some Taiwanese viewers linked the work to a particular method of Zen meditation on the awareness of time in silence and considered the work critical in the way it provided such a metaphorical implication. Others thought the work critical in the way it provided such abundant visual information for each single second, with others saying that *TimeFlower* encouraged them to wonder about the historical path of time representation through such abstracted visualisations. Notably, most viewers showed interest in how the visualisation could be applied creatively in different environmental settings, such as a projection onto a natural landscape, or on a wall of an abandoned building. One viewer suggested that the sound of the tick played a critical role, since it was the main indication that this work has the form of clock. Audience feedback also indicated that the blur effect was helpful in inducing a sense of meditation when experiencing *TimeFlower*, that is, a mode of consciousness that was more effortless, relax and calm.

5.2.5.2 *Self-reflection*

Through audience feedback, we could consider *TimeFlower* a Wundermaschine in how it turned the visualisation of time into a peculiar event by presenting time in occurrent means (discussed in section 3.5.6). It suggested spiritual implications as it created an audience

experience that links to meditation and Zen practice. *TimeFlower* also suggested that as well as the visual aspect, the physical, material and even aural dimensions of the time mechanism could be carefully examined in future practices. The sound of the tick and the regular, incremental turning inherent in mechanical clocks, therefore, may be helpful elements for constructing a wondrous machine. The audience feedback suggested that *TimeFlower*'s concept could be applied creatively in different environmental settings, and also encouraged this research to further explore alternative 'epochal' mechanisms (discussed in section 3.5.5) that embodied the techno-historical unrealized dreams of time technology. This was accomplished in later practice using an *Arduino* board with environmental sensors and an assemblage of laser-cut MDF forms cut into dynamic mechanisms. A more environment-correspondent sensor and actuator system and a sound generating mechanism through wood friction were also developed between January and April 2014 (described in section 5.6).

5.2.6 ***Implications: Toward a Media Archaeology of Clock Mechanism***

The *TimeFlower* experiment reflected my interest in achieving the metaphorical and spiritual facets of canonical Wundermaschinen, and the 'information-oriented' aspects of computer-assisted fabrication. Through this experiment, new inquiries emerged. Firstly, could alternative representations of time (particularly those embodying a cultural and metaphorical context) arouse curiosity and create visual complexity? Secondly, could a more spiritual implication be explored through time mechanisms, especially those which revealed the richness of time? In order to further explore the interlinking between time mechanisms and human spirituality, this research conducted the media archaeology described in the next two sections.

5.2.7 *New Knowledge Occurred in the Making*

The making of *TimeFlower* allowed a notion of ‘magic performance’ to be adopted in visual design. It is by hiding the actual information (current time) that dominates *TimeFlower* that can engender wonder in the audience. This course of making also suggests that the development of artwork through *Processing* can be a nonlinear progress. This is mainly because that by playing with the code in a reciprocal manner, unexpected creative outcomes may emerge. Please see Appendix 14 for more details.

5.3 From Historical Clock Metaphors to Unrealized Dreams

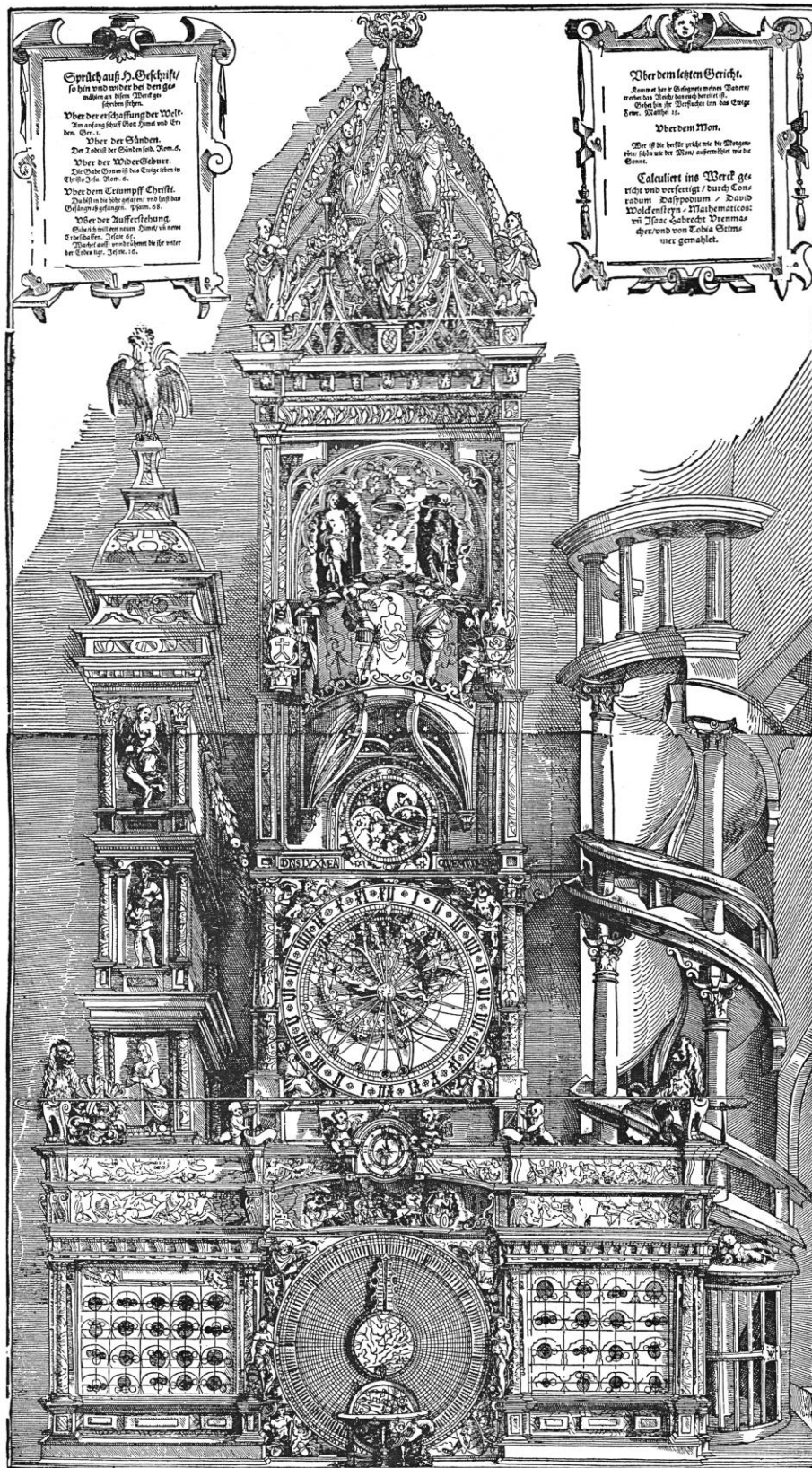
This section re-adopts the means of media archaeological exploration (applied in Chapter 4) looking for unrealized/forgotten dreams as a developmental context for a contemporary practice investigating the Wundermaschinen. I will review two types of clock metaphors, examining how clock mechanisms embody imageries of both ‘divine mechanism’ and ‘social dreams’ (in section 5.3.1 and 5.3.3). These two imageries will be juxtaposed with contemporary artefacts constructed by artists (in section 5.3.2 and 5.3.4), in order to locate a more specific design context for later practice. The slight difference in this method (compared to Chapter 4’s media archaeology) is that it is concerned more with how the continuous imageries in technology could be specifically tackled by means of computational-assisted making.

5.3.1 *Mechanism of Divinity: Strasbourg Astronomical Clock and Natural Theology*

Technological media could represent the regularities of human life and the pursuit of transcendental knowledge, such as divine and virtue. For example, by the 14th century, clocks were part of the standard furnishing of monasteries and churches in Europe, and were becoming increasingly complex in design. Sets of tuned bells, sometimes set in wheels, had been in use for at least three centuries, to call the hours of prayer throughout the day for the

monks. These monastic clocks possessed a deeper meaning in medieval thought. The machine that seemed to imitate or even improve upon monastic tradition represented the summit of the engineer's art: a piece of design that connects human life with divinity. The *Strasbourg Astronomical Clock* (Figure 52) completed in 1574 was one of the remarkable examples.

The *Strasbourg Astronomical Clock* was remarkable both for its complexity as an astronomical device and for the range and richness of its decorations and accessories. Together with the many dials and indicators - the calendar dial, the astrolabe, the indicators for planets, and eclipses - the clock was also well endowed with paintings, moving statues, automata, and musical entertainment in the form of a six tune carillon. The paintings were large panels that depicted the three Fates, Urania, Colossus, Nicolaus Copernicus, and various sacred themes, including the rewards of virtue and vice, the Creation, the resurrection of the Dead and the last judgment, amongst others. The design incorporated technologies of architecture and decorative arts, and many metaphorical techniques. For example, a bird made of copper, iron and wood, as a symbol of Christ's passion. At noon it flapped its wings and spread out its feathers. It also opened its beak, put out its tongue, and by means of a bellows and a reed, crowed.



Tobias Stimmer, Die Straßburger Münsteruhr,
 Holzschnitt, 1574

Figure 52 Strasbourg Astronomical Clock. Woodcut by Tobias Stimmer (1574)

The setting of the *Strasbourg Astronomical Clock* made imageries that were mechanical and scientific inseparable from the religious and metaphorical. And it was this kind of ‘hybridization’ that directed the discourse of teleological worldviews in the following centuries. By ‘hybridization’ I mean it was the specific design and installation setting of the artefact that allowed it to embody diverse meanings and discussions in different disciplines. For my research, there are two discourses that were particular considered: one is the concept of ‘clockwork universe’, the analogy between clock mechanisms and heavenly motion (Bedini & Maddison, 1966; Friedman, 1984). The other is the Teleological Argument (or Argument from Design) in Christianity, the discourse on God’s existence and essence which was directed by the analogy between clockmaker and the Creator of the universe (Paley, 1809). This comparison of the clockmaker with the Creator was critical in the late Middle Ages as it became the basis for most subsequent clock metaphors and later developed into a formal simile for the existence of God, the so called Argument from Design, that played such a prominent role in theological discussions of the seventeenth and eighteenth centuries.

William Paley’s nineteenth century book *Natural Theology* (or Evidences of the Existence and Attributes of the Deity) was one of the notable works describing the God-Clockmaker analogy. This God-Clockmaker analogy (also called the Watchmaker Analogy) was used to support arguments for the existence of a deity and for the intelligent design of the universe, based on reason and ordinary experience of nature. English scholars like John Ray and William Derham worked to distinguish this branch of theology from traditional revealed theology (which was based on scripture and religious experience) and also from transcendental theology (which was based on a priori reasoning). Paley’s argument was constructed around a series of examples, such as finding a watch (book Chapter I):

“There must have existed, at some time, and at some place or other, an artificer or artificers, who formed [the watch] for the purpose which we find it actually to answer; who comprehended its construction, and designed its use. ... Every indication of contrivance, every manifestation of design, which existed in the watch, exists in the works of nature; with the difference, on the side of nature, of being greater or more, and that in a degree which exceeds all computation.” (Paley, 1809, pp.1–8)

And the existence of finely adapted mechanical structures in animals (book Chapter VII):

“ Why does the gland within the ear separate a viscid substance, which defends that passage; the gland in the upper angle of the eye, a thin brine, which washes the ball? Why is the synovia of the joints mucilaginous; the bile bitter, stimulating, and soapy? Why does the juice, which flows into the stomach, contain powers, which make that bowel, the great laboratory, as it is by its situation the recipient, of the materials of future nutrition? These are all fair questions; and no answer can be given to them, but what calls in intelligence and intention.” (Paley, 1809, pp.78–91)

Paley (1802) contended that insofar as organic lives were constructed on mechanical principles, to that extent they were machines and not merely analogous to machines. Their origin, therefore, was to be found in the same intention as that of any other machine. In this realization of the identity of mechanical principles in both man-made machines and nature, Paley believed that he had an argument for the reality of God that enabled natural theology to transcend a mere teleological analogy, which based its conclusion on the purposeful association of means and ends found in both natural and human contrivance.

The *Strasbourg Astronomical Clock* and Paley’s *Natural Theology* demonstrated how a humankind-made timepiece based on mechanical principles allowed a series of discussions on philosophy of religion, including the relationship between the Creator and the world, or the

essence of divinity, through a hybrid setting. As a practitioner/researcher, this review showed a continuous dream in clock technology: the making of a subtle mechanism that is metaphorical and complex in its ‘performance-like setting’ (section 3.5.3), and that forms specific connections between the experienced (natural) world and the divine world. This media archaeology shows that clock mechanism can be an artefact that transcends the natural and the ultimate, through its hybrid setting. The question, then, is how do we tackle this dream utilizing computer-assisted fabrication?

Research also affirmed that clock mechanisms designed in later Middle Age Europe imitated the heavens not only in precision of movement but also in an untiring and continuous motion, as a working model of nature (Pacey, 1992). Observing a clock mechanism imitating nature could be considered participation in ultimate reality, for it shared the nature of self-subsistent being, and the clock “prompts us to imitate those movements of serenity, wisdom and peace in our souls” (Moevs, 1999, p.67). The later Middle Age European clock as mechanism of divinity showed that technology could not only be metaphorized as a regular pattern of organic life, or work as an emblem of human intelligence, but also, through a specific design, could be a critical material form that allowed the revelation of the transcendental or the ultimate.

5.3.2 *Mechanism of Divinity: Wang Zi Won’s Mechanical Avalokiteśvara*

A contemporary but alternative exploration of such ‘mechanism of divinity’ could be found in South Korean artist Wang Zi Won’s work. Zi Won constructs intricate mechanical figures of Buddha and Bodhisattva that appear to be in meditation or enlightenment. The electrically powered figures are merged with numerous mechanical components that at times resemble halos or lotus flowers and simultaneously move the humanoid figures through repetitive motions. The artist states his intention is to examine a future where humans, the spiritual and

technology merge, something he views in a particularly positive light. As Dukwon Gallery records:

“The artist predicts that in the future humans will evolve and adapt themselves to enhanced science and technology just as men and animals in the past evolved to adapt themselves to their natural circumstances. He sees this future as our destiny, not as a negative, gloomy dystopia.” (Shin, 2014)

For example, *Mechanical Avalokiteśvara* (2011, Figure 53) is an intricate, porcelain, mechanical figure that mimicks the gestures of a thousand-arm Avalokiteśvara, a male Bodhisattva in Buddhism. Referring to this work, Zi Won says that he considers it important to “escape from human bondage in order to achieve harmony between men and machines” (Shin, 2014). He proposes that this harmony can be achieved through the practice of mechanical-Buddha-making and the spiritual enlightenment behind the practice.

As a practitioner exploring Wundermaschine, the construction of Zi Won’s mechanical Buddha somehow reflects the techno-historical dream of ‘mechanism of divinity’. Similar to historical clocks, Zi Won creates representational figures of a deity and intentionally links the mechanism’s design with the philosophy of such religion. For example, his work often embodies ideas of harmony in Buddhism and images of circles found in Buddhist teaching. The multiplication of the figure in Zi Won and in Mandala creates a form that is neither figurative nor non-figurative, and it becomes the intimation of wonder. Zi Won’s designs successfully intrigue the observers, for they embody a dream of technology – showing a continuous movement of serenity, wisdom and peace.

Juxtaposing Zi Won’s mechanical Buddha with this research’s preceding analysis, we might find Zi Won’s works raise some critical inquiries. Firstly, Zi Won’s mechanical designs are

considered less ‘epochal’ (section 3.5.5). They possess less ability to multilaterally transform the relations/characters of other technologies (as the computational or clockwork have achieved). They also possess less ‘sensitivity of living’ (discussed in section 3.3.3), as they do not perform any responsive behaviour to the human viewer. Secondly, the ceramic figures of Buddha seemed to be too representational and thus lose some of the critical metaphorical and curious quality of the other artefacts discussed.



Figure 53 *Mechanical Avalokiteśvara* (2011) by Wang Zi Won

The different intention demonstrated in Zi Won’s work helps highlight my research’s specific concern of ‘machinery of curiosity through occurrent processing’ (section 3.5.6) and ‘information-oriented visual complexity’ (section 3.5.2). My research aims to form a contrast to Zi Won’s work in the practice of Wundermaschine. It was the converse notion found in Zi Won’s work and the media archaeological study of historical mechanisms of divinity that directed this research to another potential context. That is, a computer-assisted fabrication that

tackles the unrealized dream of ‘responsive movements of serenity, wisdom and peace’ (which will be further explained in section 5.4).

5.3.3 *Mechanisms of Social Dream: The Later Middle Age Clock as Civil Philosophy*

As I have contended in section 3.3.2, clockwork presented an order, rationality and predictability that was lacking in reality. In later Middle Age Europe, the clock represented the greatest conceivable contrast to the prevailing reality in which it was built, with the collapsing political and social order of the real world. The breakout of the English Civil War in 1642 revitalized Thomas Hobbes’ mechanistic understanding of human beings and their passions. Hobbes postulated what human life would be like without government – what he called a “war of all against all” (Hobbes, 2006). As a radical mechanist among political philosophers, Hobbes recommended a watchmaker’s approach to political analysis in his Preface to *De Cive* (1642):

“For as in a watch, or some such small engine, the matter, figure, and motion of the wheels cannot be known, except it be taken in sunder and viewed in parts, so to make a more curious search into the rights of states and duties of subjects.”
(Watkins, 1955, p.132)

At the same time, Newton and Robert Boyle’s approach to mechanical philosophy was also promoted by rationalists to combat the emotional and the threat of atheism (Westfall, 1958, p.200). English deists also used Newton’s discoveries to demonstrate the possibility of a ‘natural religion’. Newton’s clockwork universe, and the conception of the universe based upon rationally understandable laws, became one of the seeds for Enlightenment ideology (Gribbin, 2003, p.241). The clock thus became a material account supporting the civil philosophy in later Middle Age Europe. In literature, the prince was often compared to a public clock or dial that could encourage his subjects’ disciplined behavior. John Webster announced in *The White Devil* (1612) the influence of the prince-clock metaphor:

“The lives of Princes should like dials move,
Whose regular example is so strong,
They make the times by them go right or wrong.” (Praz, 2001, p.223)

and similarly, Christoph Lehmann in his *Florilegium politicum* (1630) :

“A Prince and ruler is the nation’s clock,
Everyone will follow him in his conduct,
as he follows a clock in his daily affairs. (Cohen, 2009, p.32)

The analogies here are between the clock mechanism and the ruler as a unique, commanding individual. The distinction between humans and machines was intentionally blurred, since the clock helped the subjects to regulate themselves. The entire state was also regarded as complex interacting clockwork. The state, as Henri Duc de Rohan contended, was a: “huge machine composed of so many parts... encumbered by its own weight that moves by its secret spring.” (deRohan & Arnd, 1725, pp.10–11).

When more and more countries on the European Continent committed themselves to the absolutist form of monarchy, or returned to it after Civil War (in the case of England), the clockwork image became increasingly the controlling analogy for the state. In the paintings of the seventeenth century, rulers and other dignitaries were commonly portrayed next to clocks, as seen in (Figure 54 and Figure 55).

These historical examples show that the state, as an artificial construction, was often compared to a mechanical clock. The clock represented an ideal and robust world order and



Figure 54 *Portrait of Mariana of Austria*. Diego Velázquez. Madrid, c. 1653. Vienna, Kunsthistorisches Museum

was often adopted by political authority as a metaphor for “legitimate or complicated secrets of state”, or by the court to “elucidate its conflictive relationship to political secrecy and to weight some of its key moral and intellectual conflicts” (Wolfe, 2004, p.68). In this sense, the clock was considered a mechanism of ‘social dream’, which shows an ideal order.



Figure 55 *Portrait of Armand Jean du Plessis de Richelieu*. Philippe de Champaigne, c. 1636. France, Condé Museum

However, interestingly, it remained a dream. This is because the makers and spectators only forged analogies between political mystery and the subtlety of machinery. This analogy was shown as representational metaphor, which only expresses the representative character of a sign (clock) by showing a parallelism in something else (authority). Such analogy was

relatively vague and general, and made the clock somehow an artefact of failure: a mechanism of social dream/ideal which did not propose critical interventions within existing social systems and never truly inspired debate or catalyzed social change. The clock mechanism was only an imagery that was dominated by the authority, to elucidate their monarchy and controlling power.

From the perspective of the contemporary practitioner/researcher, such vague analogies of clocks in the later Middle Age Europe reveal another potential context for experiment. Limited by the technology then, the clocks were used only as material metaphors for the social dream/ideal of a rationality and predictability that was lacking in reality, but they could not convey information about any specific social problems or requirements that were significant in that particular age. Therefore, new inquiries emerged: how do we design a mechanism that directly embodies a specific social dream/ideal, and not a vague abstraction? Particularly, how do we tackle this inquiry in response to the experimental aspects of computer-assisted fabrication (reviewed in section 3.4.3)?

5.3.4 *Mechanism of Social Dream: Gilberto Esparza's Plantas Nómadas*

A contemporary but distinct exploration of such 'mechanism of social dream' can be found in Mexican artist Gilberto Esparza's works. Esparza often works with electronic and robotic resources to investigate the impact of technology on human daily life, social relationships, environment and urban structure. He has carried out projects regarding alternative energy sources and often uses forms of technological recycling and hybrid processes that are both analogical and computational. Therefore, his fine-designed machineries are often constructed for, and presented in, a specific environment, and demonstrate a perceivable process that shows empathy with nature.

For example, according to Esparza, *Plantas Nomadas* (Nomadic Plants, 2011, Figure 56) is an art-research project that comes to:

“... reflect on the environmental and social impacts generated by human activity: production systems, the concentration of wealth, the maintenance of gigantic urban centres, the excessive exploitation of natural resources, resistance to an energy transition, and in short, the lack of awareness to find ways of life that relate to empathy with nature.” (Esparza, 2013)

Esparza's *Plantas Nomadas* aims to bring together organics and machinery with the intention to confront and inhabit areas of ecological disaster. The protagonist of this piece is a kind of bio-cybernetic entity, a self-contained robotic ecosystem in which plants, bacteria, electronics and machinery form a symbiotic system and a process of parallel cleansing and sustenance.



Figure 56 *Plantas Nomadas* by Gilberto Esparza (2011)

Once a polluted water source has been located, *Plantas Nomadas* uses a suction pump to fill its own reservoir. Microbes within the robot's fuel cells extract contaminants such as heavy metals or toxic chemicals from the collected water, the by-products of this process providing power for the machine and clean water for the plants. In addition, *Plantas Nomadas* processes contaminated water and fuel in its cells via a colony of indigenous bacteria, which feeds on nutrients and transforms them into electricity to be stored by the energy harvesting system (Figure 57). Oxygen is released as a by-product of this energy cycle. For Esparza, *Plantas Nomadas* is not only a mechanism adapted to the changed environment, but can also restore the energy available on earth.

In this research exploring Wundermaschine, *Plantas Nomadas* provides a suggestive example. It can be regarded as a 'performative-like' artefact formed by various agencies that coexist in symbiosis to survive in the setting of a contaminated environment. More critically, demonstrating a mechanical process, the robotic mechanism of *Plantas Nomadas* calls attention to a critical issue of the 21st century: efficient use of energy, that is, maximizing the ratio of energy produced to energy consumed. It might thus be regarded a 'machine of revelation' – embodying a clear social dream of the harmonious symbiosis of human and other organic lives.

Esparza's creative work combined with the media archaeological findings on historical clock metaphors as social dreams directed this research to another potential context. That is, a computer-assisted fabrication that tackled the unrealized dream of 'mechanism of social dream' and particularly included critical awareness of environmental issues, and the symbiosis of human and other life forms. This research concerned how a future relationship between human, plant and machinery could be speculated through a designed mechanism. This notion of 'nature as authority in clock mechanism' will be explained in section 5.4.



Figure 57 *Plantas Nomadas* processing contaminated water

5.4 Two Unrealized Dreams of Clock Mechanism

The preceding media archaeology and contemporary art review excavated two techno-historical unrealized dreams to be explored in practice. That is, ‘responsive movements of serenity, wisdom and peace’, and ‘nature as authority in clock mechanism’.

5.4.1 *Responsive Movements of Serenity, Wisdom and Peace*

A review of later Middle Age monastic clocks (in section 5.3.1) revealed humankind’s continuous dream of creating a ‘mechanism of divinity’; an artefact that creates experience of serenity, wisdom and peace. A review of Korean artist Zi Won’s *Mechanical Avalokiteśvara* (in section 5.3.2) further suggests that a contemporary Wundermaschine should tackle this notion with experimental aspects characterized by computer-assisted making, such as being more responsive and mimetic, or inherits a ‘sensitivity of living’ (as discussed in section

3.3.3). In order to juxtapose the contemporary and the techno-historical, this research considers the ‘responsive movements of serenity, wisdom and peace’ as an unrealized dream to be explored through Wundermaschine practice. This dream relates to humankind's desire of designing artefacts of wonder that help develop human consciousness and peace.

5.4.2 *Nature as Authority in Clock Mechanism*

A review of later Middle Age clocks (in section 5.3.3) demonstrated how technology became material metaphors for the social dream/ideal of a rationality and predictability that was lacking in reality. However, limited by the technology then, this notion of ‘clock mechanism of social dream’ could only be presented as a representational metaphor. The idea of nature as divine mechanism in *Natural Theology* (Paley, 1809) was found to be particularly intriguing and prompted consideration of how such an idea could be embodied in a contemporary design. A review of *Plantas Nomadas* also provided a potential example of ‘social design’: a mechanism that directly embodies an ideal of the harmonious symbiosis of human and other organic lives. Therefore, in a research toward 21st century Wundermaschinen, a speculative dream of ‘nature as authority in clock mechanism’ is considered critical. This dream relates to humankind's unique inquiry into constructing a better relationship with nature and organic lives in designing technology.

5.5 Toward Wundermaschine of Revelation

The reflection on *TimeFlower* (section 5.2) and the media archaeology of European clock mechanism in the later Middle Ages (in section 5.3 to 5.4) identifies a more specific potential concept of ‘Wundermaschine of Revelation’ as a design that promotes humankind’s interests in the pursuit of wisdom and peace, the symbiotic relationship between human and nature, and the realization of the specific social dream and ultimate ideal in artefact design. The

following section will demonstrate the developmental context, design aesthetics, and implications of a Wundermaschine prototype that materializes this media archaeology.

5.6 Experimental Project – Botanical Universe (Apr –Dec 2014)

5.6.1 *Methodology*

Following the thread of developing Wundermaschinen of Revelation, the making of *Botanical Universe* was to explore a juxtaposition of physical formations of canonical clockwork and responsive characteristics of digital technology. This project was developed with a method of interdisciplinary approach to making (section 1.5.3) utilizing crafting skills, interactive programming and display techniques. *Processing* and *Arduino* were utilized to achieve a notion of botanically-driven clock (see section 5.6.4 for more detail). *Botanical Universe* was developed with a media archaeological review on the unrealized dreams of clock mechanism in history to find parallels and potential discussion (explored in section 5.4). The final version of *Botanical Universe* was displayed in Culture Lab for feedback and reflection (section 5.6.7). Based on the feedback and reflection, the implication of this practice will be suggested in section 5.6.8.

5.6.2 *Aims and Developmental Context*

In this research context, the primary aim of *Botanical Universe* (2014) (see Figure 58 and Appendix 7 and 8) was to investigate how the two techno-historical unrealized dreams of ‘responsive movements of serenity, wisdom and peace’ and ‘nature as authority in clock mechanism’ could be tackled in a new media design. It was also driven by an intention to materialize the characteristics of ‘21st century Wundermaschine’ speculated in section 3.5: ‘performance-like setting for specific sensuousness’ (section 3.5.3), ‘embodying multiple

epochal technology’ (section 3.5.5), ‘machinery of curiosity with occurrent processing’ (section 3.5.6) and ‘object of philosophical argument’ (section 3.5.7).

5.6.3 *Design, Implementation and Aesthetics*

The practice of making *Botanical Universe* investigated how the juxtaposition of metaphorical images could be applied in the development of a mechanical and responsive artefact. It demonstrated a mechanism where a plant (ivy) was applied as an agent to detect the environmental conditions and directly influence the speed and pattern of a kinetic time-mechanism. Its mechanical design particularly adopted the previously stated notion of ‘hybridization’ (in section 5.3.1) as the work was designed to operate in an organic outdoor environment (Figure 59 and Figure 60). The title of this work references ‘clockwork universe’ (or mechanical universe), indicating a clear techno-historical connection to a concept that originated in later Middle Age Europe and that compared the universe (macrocosm) to mechanical clockwork (microcosm). *Botanical Universe* was a design for re-imagining human-world relationships through creatively juxtaposing the function, expression and mechanism that was similar to the clockwork automata with that of the computational era.



Figure 58 Exhibition setting of *Botanical Universe* in Space 5, Culture Lab, Nov 2014





Figure 59 *Botanical Clock* operating in an outdoor setting, Newcastle University, Nov 2014



Figure 60 Detail of *Botanical Clock*

5.6.4 General Technical Description

Botanical Universe assembled two mechanisms: the *Botanical Clock* in the centre and two *Circular Mechanisms* on either side. A main *Arduino UNO* board was used to control their operating speed and pattern in response to the environmental data detected on-site. The two mechanisms were drawn in *Adobe Illustrator* and the file exported to a laser cutter for cutting MDFs of 2, 3 and 6 mm in thickness (Figure 61). The burned edges created by the laser cutter were intentionally kept, creating a recycled quality to respond to the notion of planned obsolescence in electronic consuming culture (as reviewed in section 3.2).

5.6.4.1 Botanical Clock

The *Botanical Clock* was a mechanism that indicated the passing of time in response to the

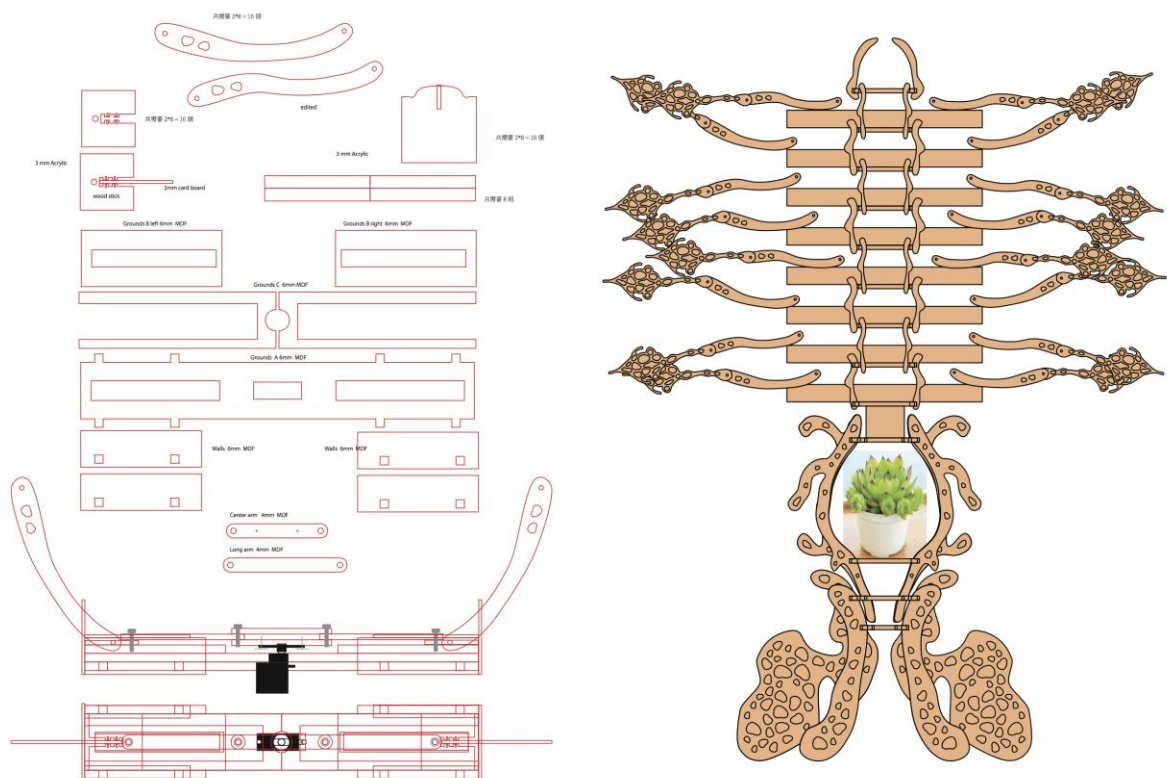


Figure 61 Design schematics of the ticking mechanism (left) and the whole structure (right) of *Botanical Clock*

environment. An ivy plant was employed as an agent to detect environmental conditions and influence the speed and pattern of a kinetic mechanism. To achieve this, the ivy plant was installed in the centre of the *Botanical Clock* with four environmental sensors that monitored the temperature, light, air humidity and soil moisture of the space (Figure 62). The main *Arduino UNO* board was coded to compare the environmental data with suitable conditions for ivy, according to care instructions ('How to Grow and Care for Ivy Plants', 1997). An *Adafruit 16-Channel PWM Driver* was then connected to the main *Arduino UNO* to control eight servomotors and each of these motors controlled two hands, including the turning speed and angle. Since each of the motors could be controlled separately, the mechanism could perform more than eight different ticking modes depending on the environmental conditions of the plant. The clock could also tick in different rhythmic patterns. A meter showing the soil humidity and light quantity was displayed in the centre of the *Botanical Clock* (Figure 63 and Figure 64) to show the current environmental conditions.

Such design using symbolic figures of sun, moon, water and rock aimed to spark curiosity in the viewers by following the 'metaphorical visualisation' of canonical Wundermaschinen such as the clockwork automata reviewed in section 3.3.2. The *Botanical Clock* processes events (environmental change) as they occur, allowing the mechanism to react dynamically, and create correspondent effects (various mechanical motion) on the recipient and space. As I have contended earlier, such means creates a sensitivity to organic lives and is considered to have further potential in influencing human activities. The *Botanical Clock* aims to materialize what this research have discussed as 'machinery of curiosity through occurrent processing' in section 3.5.6.

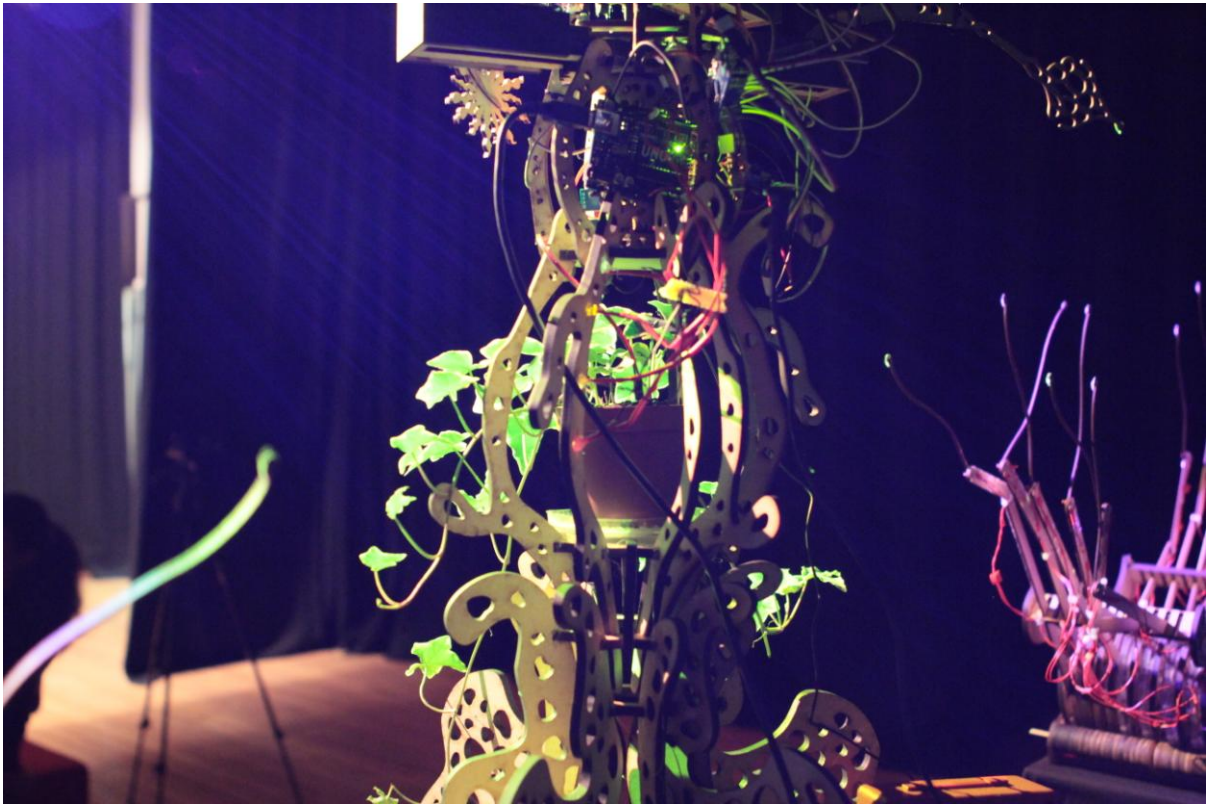


Figure 62 An ivy plant was installed in the centre of *Botanical Clock* with four environmental sensors



Figure 63 A meter showing the soil humidity (top) and light quantity (bottom) on *Botanical Clock*. For the light quantity meter, the shape of sun indicated bright environment while the shape of moon indicated dark environment

5.6.4.2 Two Circular Mechanisms

The two *Circular Mechanisms* (Figure 65 and Figure 66) were mainly designed to incorporate the historical social dream of ‘regularity’ (reviewed in section 5.3.3). In each of these turning mechanisms, an *Arduino UNO* board was used to control two 5V stepper motors, which together drove one laser-cut MDF gear that attached to the indicators. This made the mechanisms able to turn at various speeds and in both directions.

5.6.4.3 Sound design

The sound design of *Botanical Universe* aimed to provide a techno-historical backtracking by bringing a forgotten mechanical wooden sound back to the present. A pair of contact microphones and amplifiers (see Figure 67) was attached to the wooden structure to directly enhance the vibration caused by the eight ticking motors and the friction between the wooden hands. The outcome was an organic resonance created by the noise of motors and gears, and sounds from the friction between the wood boards.

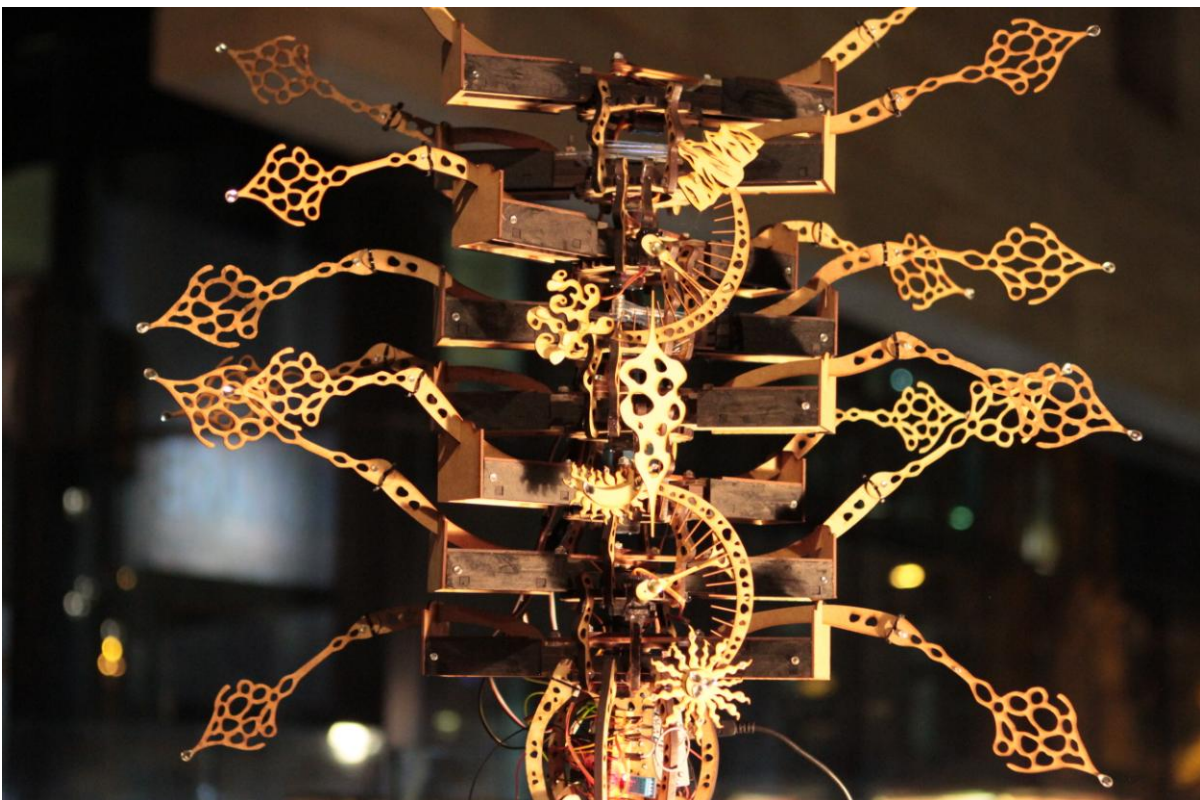


Figure 64 In dark environment, the light quantity meter on *Botanical Clock* turned to the ‘moon position’

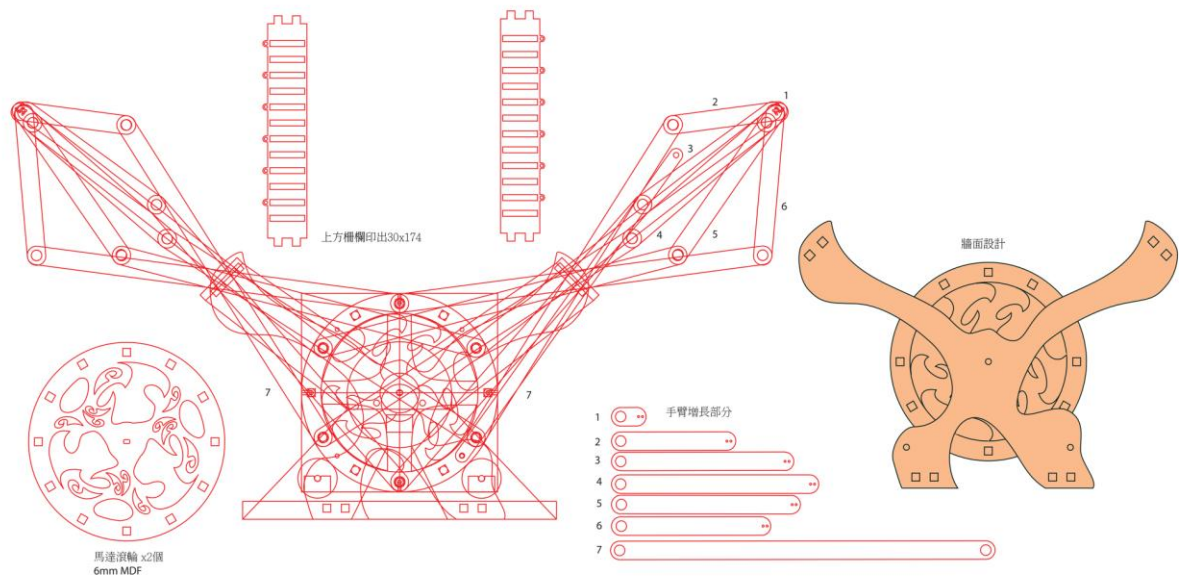


Figure 65 Designing schematics for the two circular mechanisms in *Illustrator*

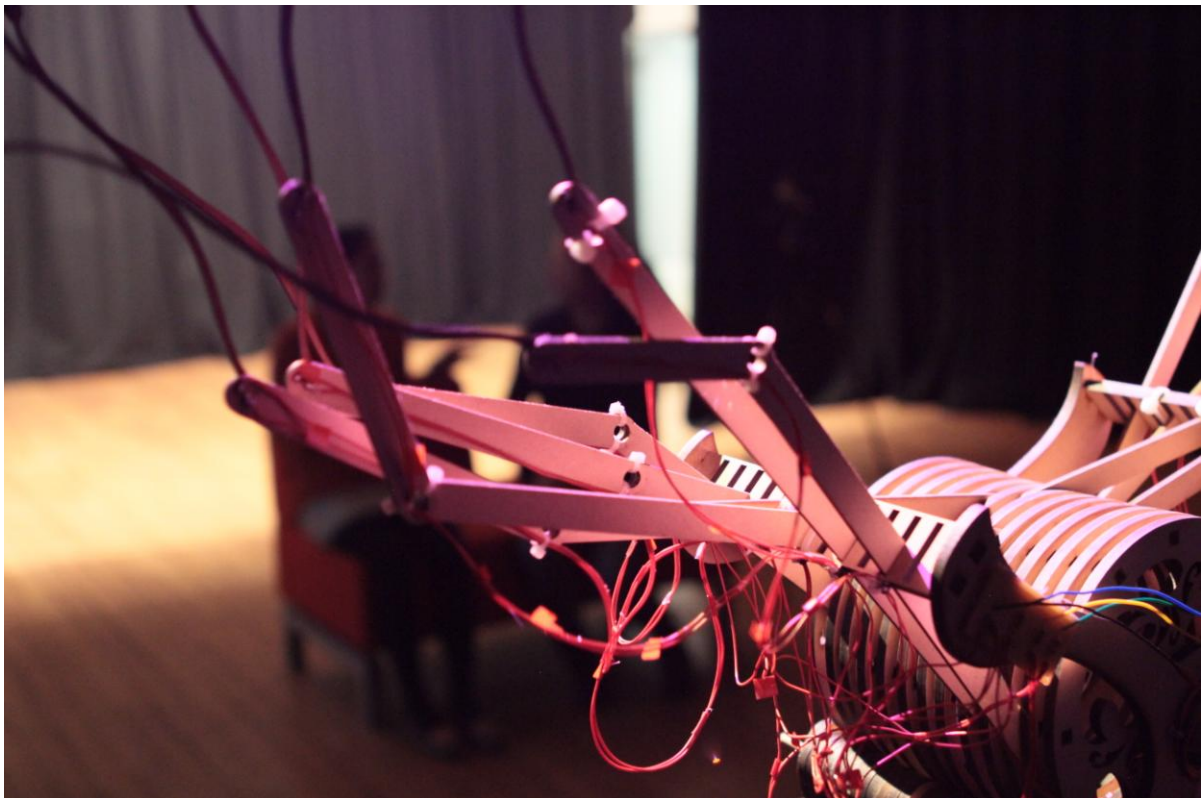


Figure 66 One of the *Circular Mechanisms* (a view from behind). They were constructed with MDF, *Arduino* board and stepper motors

5.6.5 *Technical Description: Responsive Movements of Serenity, Wisdom and Peace*

In order to achieve ‘responsive movements of serenity, wisdom and peace’ (section 5.6.5), a mechanism similar to the image of the Buddhist Deities Chakrasamvara and Vajravarahi (Figure 26) was designed for *Botanical Clock* to indicate the health of the ivy by presenting different moving patterns and ticking speeds of the hands. For example, when the environmental condition was optimal for the plant, the hands would tick in a progressive pattern and at a faster speed. When the environment was not suitable for the plant, the clock would only move half the hands slowly. The movements were designed to progress slowly and smoothly in order to create a sense of serenity and peace. For creating a mysterious and immersive experience, the work was installed in a dark environment for its indoor exhibition and some reflective jewels were attached on the tips of the *Botanical Clock* and *Circular Mechanisms*.



Figure 67 Two small amplifiers were set behind the *Botanical Clock*

5.6.6 *Technical Description: Nature as Authority in Clock Mechanism*

As I have described in 5.6.4, the ivy plant played an authoritative role in *Botanical Clock*. The ivy's condition in the space determined the rhythm and speed of the ticking mechanism. That is to say, *Botanical Clock* engaged the unrealized dream of 'nature as authority in clock mechanism' (discussed in section 5.4.2). For a clearer presentation of this notion, a video documentation has been made showing *Botanical Clock* operating in different environments including indoor and outdoor, day and night (Figure 68), which informed the viewers of how the work may perform differently in other environmental conditions.

The notion of creating 'spiritual resonance' (discussed in section 4.4.2) was particularly embodied in the exhibition setting of *Botanical Universe*. For its indoor exhibition in Culture Lab, the work was installed in a dark environment and reflective jewels were attached to the tips of the *Botanical Clock* and *Circular Mechanisms*. Simultaneously, a coloured light was



Figure 68 The exhibition setting of *Botanical Universe* in Culture Lab, Nov 2014, which included a video documentation of *Botanical Clock* installed in various environmental situations

projected onto each of the three mechanisms, so that when the indicators moved the work dynamically reflected unexpected colours around the room, creating a metaphorical microcosm of heavenly motion. The coloured light projection used gradual colour changing software coded in *Processing*. The colour changed completely to another setting every fifteen minutes, which also implied the passing of time periods, a microcosm of seasons.

5.6.7 *Audience Response and Self-reflection*

Botanical Universe was exhibited in Space 4, Culture Lab, Newcastle University, UK in Nov 2014 (Figure 58). It was also presented in a conference paper published at *ISAT 2015* Conference of Art and Technology in Taipei, Taiwan (Li, 2015a).

Most of the viewers walked around and discussed the work in small groups. Many stood close to the work to observe it in detail. The viewers mainly shared positive comments on the mechanism's design skill, the sound, installation setting and visualisation of the work. Some audience linked the mysterious atmosphere *Botanical Universe* created to some kind of "esoteric mechanical practice". Some direct discussions with the audience showed that they particularly liked the mechanical sound *Botanical Universe* created. It was "an organic whisper between the wooden pieces", said one of the audience member. Another said that the installation is "very intriguing for there is very much detail in the work". The feedback suggested *Botanical Universe* generated an experience of curiosity and exploration, which is an intimation of wonder. Amongst much feedback, two topics were considered in more detail in the next two sections.

5.6.7.1 *Audience Response: Slow Computing and Conscientious Consuming*

Some of the viewers in Culture Lab discussed with me the emerging movement of *Slow Computing* named by journalist Nathan Schneider (Hockenberry, 2015), which was a homage

to the *Slow Food* movement and called for conscientious consuming of technology. Much as the *Slow Food* movement emphasized local economies, traditional knowledge and ecology, *Slow Computing* meant not merely opting for the most competitive, profit-driven hardware and software, but instead building a community that concerns computer as constant companions and critical artefact that shapes our experience. As Schneider (2015) suggests:

"Each of us can practice a spirituality of technology centered around the use of simple, open, appropriate tools rather than always embracing whatever is newer, faster and supposedly better... Priorities like these resonate through our history, to old values of craft, community and the commons." (Schneider, 2015)

This audience feedback linked my work to the emerging culture of *Slow Computing* promoting collaboration rather than competition, as well as a spirit of craftsmanship-for-its-own-sake. In this sense, the audience member considered that the work conveyed the critical question of not whether to use technology or not, but which technologies to use, and how. Research into *Slow Computing* showed it shared with *Botanical Universe* the intention to change the user's relationship to machines, making the user wonder in the time he/she spent with them, and connected to communities of people who build open source artefacts for the sake of individualized intention more than profit. *Slow Computing* also shared the spiritual values of craft, community and communication with the fundamental principles behind the making of *Botanical Universe*. This reflected the intention of 'object of philosophical argument' (section 3.5.7), since the artefact has the potential to trigger discourse and knowledge exchange.

5.6.7.2 Audience Response: Plant as Agent?

The second important comment linked to how some viewers challenged my approach of 'nature as authority in clock mechanism'. Some felt the way I decided what was a good or bad environment for the ivy was too restrictive and problematic concerning my original intention of

a botanically driven clock. Concerning this comment, the future mechanism should be able to detect how “well” the plant is by a mechanism more free of any individual’s interpretive or cognitive decision. For example, one technical suggestion for this was to retain the micro-voltage directly from the plant’s body, attaching some Op-amp microchips to turn the plant itself into a biosensor for the environment. This technique will be developed beyond this PhD study.

5.6.7.3 *Self-reflection*

In relation to audience feedback, *Botanical Universe* had shown abundant outcomes. As a materialization of two unrealized dreams of clock mechanisms (discussed in section 5.4), it was proven to embody visual complexity, a juxtaposition of the contemporary and the techno-historical, and to evoke discussion on human perception of time, ecological issues and human-machine interaction. *Botanical Universe* was historically informed in its developmental background and design aesthetics. Meanwhile, it performed phenomena that were ‘relational and occurrent’ (section 3.4.3.2) by utilizing computational technology. For example, the reflective light from the jewels and the mechanical motion of *Botanical Clock* were both in correspondence with the environmental conditions. *Botanical Universe* thus affirmed that by integrating media archaeological excavations into a contemporary design, we might explore tacit knowledge about how a clock-like machinery constructed with computer-assisted fabrication can embody dreams of techno-historical media.

5.6.8 ***Implications: Divergent Materialities of Wundermaschinen***

Considering the diverse means of material selection between *Botanical Universe* and its historical antecedents, an interesting implication emerges. As we have seen in the preceding review (in section 3.3), most canonical Wundermaschinen were constructed with delicate materials such as copper gears and pulleys, fine wood and gold leaves. The decoration of

these machineries also intended to show off refined labour and craftsmanship to the audience, as this highlighted the collector's social position (e.g. the mimetic performance dolls) or created certain illusion and trickery (e.g. *The Turk* and *The Keely Motor*). The preciousness of material plays a critical role in the wonder the canonical Wundermaschinen inspires.

Quite contrastingly, in order to tackle the unrealized dreams through practice of computer-assisted fabrication, *Botanical Universe* as a contemporary Wundermaschine utilized cheap, handy and even abandoned materials: everyday electronics, mass produced sensors, MDFs and PLA plastic. As a machinery of evoking curiosity and philosophical argument, *Botanical Universe* is similar to canonical Wundermaschinen for its 'rarity and refined labour' (section 3.5.1) and 'visual complexity' (section 3.5.2). However, *Botanical Universe* did not lure the spectators with any precious material; neither did it attract the collectors with a costly mechanism. The labour of its construction had a clearly different aim.



Figure 69 *Botanical Universe* on show in Culture Lab, Nov 2014

That is, *Botanical Universe* discarded the luxury and costly decorations, and rather focused on how new issues and thoughts could originate from the experimental assemblage of everyday electronics and materials. This made *Botanical Universe* embody a ‘divergent materiality’ compared to canonical Wundermaschinen. Such a divergent aspect, as far as this research is concerned, is one of the most intriguing insights gained through making contemporary Wundermaschinen.

The most divergent value of such materiality was that this artefact-of-intensive-labour did not aim to be possessed as an ultimate luxury product, but to engender discussions and knowledge exchange in the audience. *Botanical Universe*’s materiality can be considered rare and refined, but not in the sense of how great a cost of construction it shows off, rather in the sense of how common technology can be subtly transformed through a cautious process by the maker, into an unusual and non-utilitarian installation that aims for exploration of aesthetic and philosophical values. Such divergent materiality also seems to correspond to an emerging tendency today. While planned obsolescence purposefully ensures the soon-to-be out-of-date or useless character of new inventions, all present technologies are simultaneously new-and-old, precious-and-defective. *Botanical Universe*, as suggested by the audience feedback, is thus a practice of seeking human conscience in an era of vast technological waste.

5.6.9 *New Knowledge Occurred in the Making*

The making of *Botanical Universe* allowed this research to experiment with how laser cut MDFs could be assembled into a three dimensional sculpture without using screws. This project suggests cut smaller scale pieces to play with, which helps explore various possibilities. More importantly, *Botanical Universe* also suggests that the development of a

complex artwork can start with a simple idea, or the making of a small functional part. Please see Appendix 15 for more details.

5.7 Future Developments

The development of *TimeFlower* and *Botanical Universe* suggested another potential tendency in constructing contemporary Wundermaschinen. The creative assemblage of a clock mechanism by means of computer-assisted fabrication exemplified a ‘Wundermaschine of Revelation’. That is, by novel collage of materials, data-processing mechanisms, and sensor and actuator systems, we may create audience experience that links to the unfolding of human consciousness. This design of Wundermaschine of Revelation embodies the canonical features of ‘metaphorical’, ‘object of philosophical argument’ and ‘rarity and refined labour’, while suggesting a ‘divergent materiality’ in contemporary making. It intends to open up space for debate and discussion through tackling techno-historical unrealized dreams in clockwork mechanisms. It aims to be provocative while raising new inquiries through multiple disciplines and to propose possible future technological developments.

The juxtaposition of the computational with the clockwork, both ‘epochal’ technologies in human history (as I have discussed in section 3.5.5), is also considered intriguing for the audience. Such practice encourages the reconsideration of the epochalness of technology through creative material intervention, and suggests potential for future developments. In a finalizing project of this research: *The Flower of Time V.2* (described in section 6.4), this notion of assembling multiple epochal technologies will be further explored.

Chapter 6 The Dawn of the 21st Century

Wundermaschinen

6.1 Resume of Work Done

As stated in research questions (section 1.3), this research is driven by the aim of approaching ‘machine of wonder’ as a creative framework for contemporary media practice, and is concerned with the related aesthetic implications and media research tendencies. The thesis outline can be expressed as in the diagram in Figure 70. The various works finished during this course of study include the following:

- Two experimental information visualisation projects in the early stages as research groundwork (in Chapter 2).
- Literature reviews on canonical Wundermaschinen in sixteenth to eighteenth century Europe, and contemporary maker-culture such as open source making and digital fabrication (in Chapter 3).
- A creative framework for contemporary media practice (in section 3.5), based on the two stages above.
- Examination of two practical threads through artefact making: Wundermaschine of Correspondence (in Chapter 4) and Wundermaschine of Revelation (in Chapter 5). Both threads were explored through media archaeology, critical study of other artists’ work, hands-on media experiment and exhibition.
- Seven artefacts/artworks presented in exhibitions to gain audience feedback and reflection. (The seventh project will be annotated in section 6.4).
- Several publications produced and workshops conducted as research output (see List of Publications).

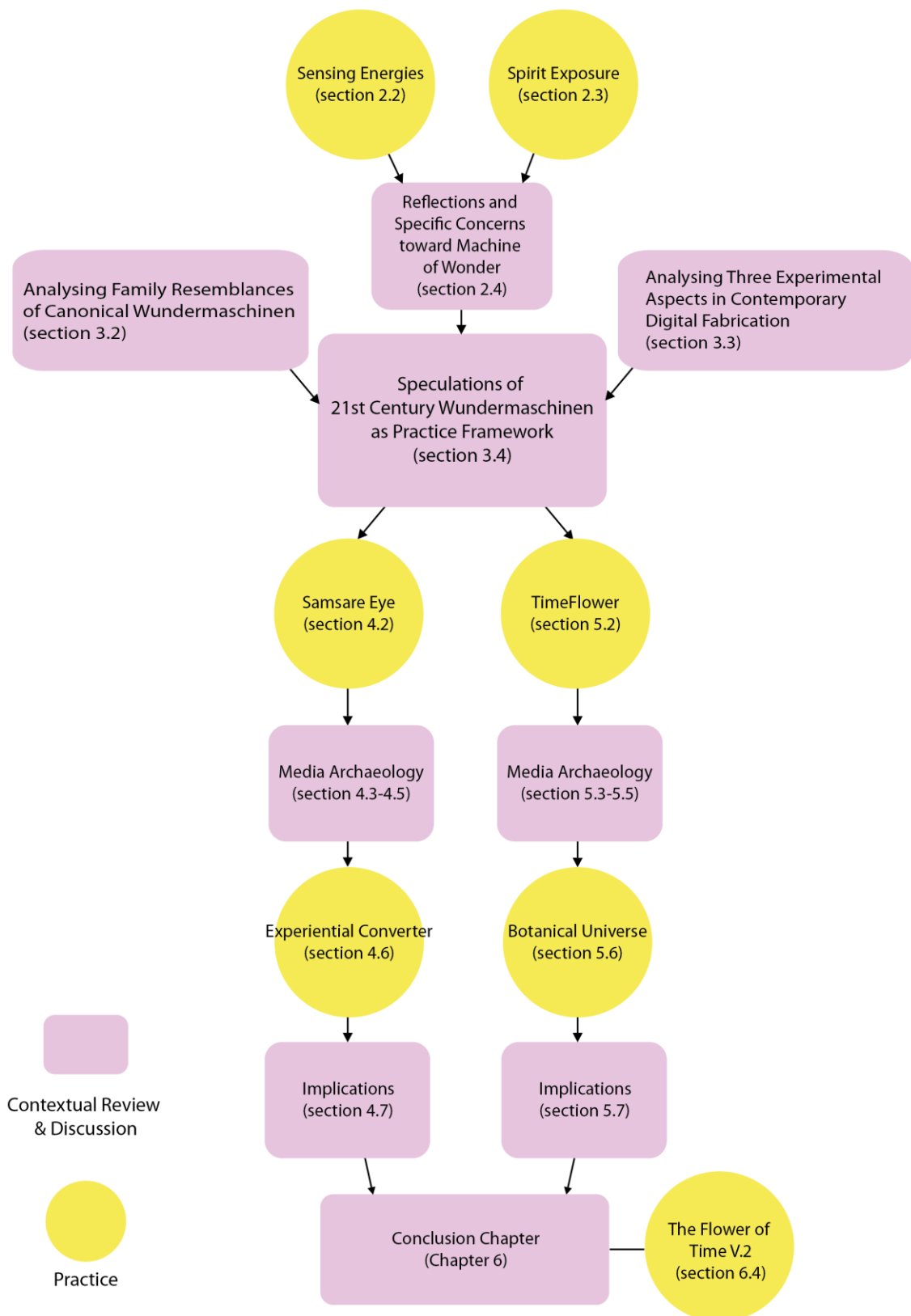


Figure 70 Thesis outline

6.2 Re-engagement with Research Questions

6.2.1 *How can we approach the machine of wonder as a framework for creative media design?*

As this research shows, through a literature review of canonical Wundermaschinen, I found the ‘family resemblance’ (Wittgenstein, 1953, 1998; Griffin, 1992) characteristics between them. Through a review of contemporary maker-culture, I analysed and reflected on the contemporary ways of making to propose three experimental aspects. These two analyses have allowed me to speculate on the possibility of juxtaposing historical Wundermaschinen with contemporary technology to explore the idea of a ‘21st century Wundermaschinen’. In addition, by conducting seven experimental media projects, these characteristics were further examined and discussed. Having done this, this study suggests that a creative framework for machines of wonder can be constructed by analysing the features of historical Wundermaschinen and contemporary methods of prototyping. Embracing Wittgenstein’s notion of “criss-crossing” (Hanfling, 1989, p.64) and Ingold’s concept of making as “meshwork weaving” (Ingold, 2013, p.132), this framework is considered to have creative potential. It suggests further practice that explores how canonical Wundermaschinen can be juxtaposed with contemporary and future technology.

6.2.2 *How can we prototype a 21st century machine of wonder and what are the characteristics of experience, potential of aesthetics, and media research tendencies involved in so doing?*

6.2.2.1 *How can we prototype a 21st century machine of wonder?*

As this research suggests, a 21st century Wundermaschine can be prototyped through utilizing computer-assisted tools. This includes software for coding such as *Processing*, *Arduino*, and *PureData*, and hardware for artefact making such as *Arduino UNO* boards, sensors, laser

cutter and 3D printer. Open source making is considered contributive to this prototyping process, as it provides a good environment that facilitates methods of ‘interdisciplinary approach to making’ (section 1.5.3) and ‘reflective prototyping’ (section 1.5.4). Media archaeology has also proven to be an important part of this process of making. It allows the practitioners to excavate unrealized dreams in the history of technology and see how contemporary technology can tackle them as intimations of wonder. This research suggests contemporary artists who are working with technologies to seek inspirations in the history of technology. For example, concerning the notion of ‘correspondence’, digital media is a tool for entanglement, which reconfigures and re-determines the presumed boundaries and properties of visual, auditory and spatial-dynamic distinction.

6.2.2.2 Characteristics of experience?

Having completed the experimental projects, the characteristics of experience created by a 21st century Wundermaschine may include the following.

- A rare and curious experience of technology that is away from daily experience of technology.
- A multi-sensory/ cross-modal experience that is information-oriented.
- An experience of a sequence of events and actions generated by technology through, or in, a particular site. Such events and actions are considered performance-like.
- An experience that evokes the audience to engage knowledge across disciplines.
- An experience of multiple epochal technologies.
- An experience that generates further discussions on human-machine relationship, contemporary issues, and future technology.

6.2.2.3 *Potential of aesthetics?*

As stated in section 1.2, this practice-based research was inspired by the multi-disciplinary nature seen in contemporary computational arts, and the ambiguous identity between artist, stage-magician and engineer shared by many contemporary creative practitioners. The experimental practices suggest the relationship between esotericism and technological artefacts as an intriguing focus for further aesthetic exploration. For example, *Experiential Converter* (annotated in section 4.6) can be considered an ‘art-machine’ or ‘performative-machine’, as it utilizes the esoteric concept of correspondence in a performance-like installation. The *Botanical Universe* (annotated in section 5.6) can be considered an ‘information-oriented sculpture’, as it is a kinetic object which intellectually responds to its environmental condition while embodying the form of clockwork. These Wundermaschinen designs can thus urge the contemporary audience to re-engage with computational artefacts from a more cultural-historical and esoteric perspective. They remind us that interaction design and esoteric practice, which many assume to be far away from each other, may be more overlapping in the future. Computational artefacts, in this sense, possess the potential to create an aesthetic experience that is generative, correspondent and dynamic, and provoke the audience to engage knowledge across disciplines.

The way information is processed and represented in my work suggests that unlimited aesthetic possibilities are there to be explored. Creative practitioners with esoteric knowledge can utilize information visualisation to arouse more contemporary issues and create cross-modal experience. This research suggests that the creative practitioners not only develop a potential visual style of information visualisation, but provoke new inquiries that relate to various domains, and by doing so, link the media art and design practice to wider socio-cultural, anthropological or techno-historical contexts. This research points to features of artefacts of interest and connect those features to matters of further concerns (see summary

picture in Figure 71). Accordingly, a Wundermaschine's aesthetics should not exclude the excavation/discussion of unrealized dreams of technology, the ultimate realm embodied in machinery design, or the reconfiguration of human intelligence and value through practice of technology.

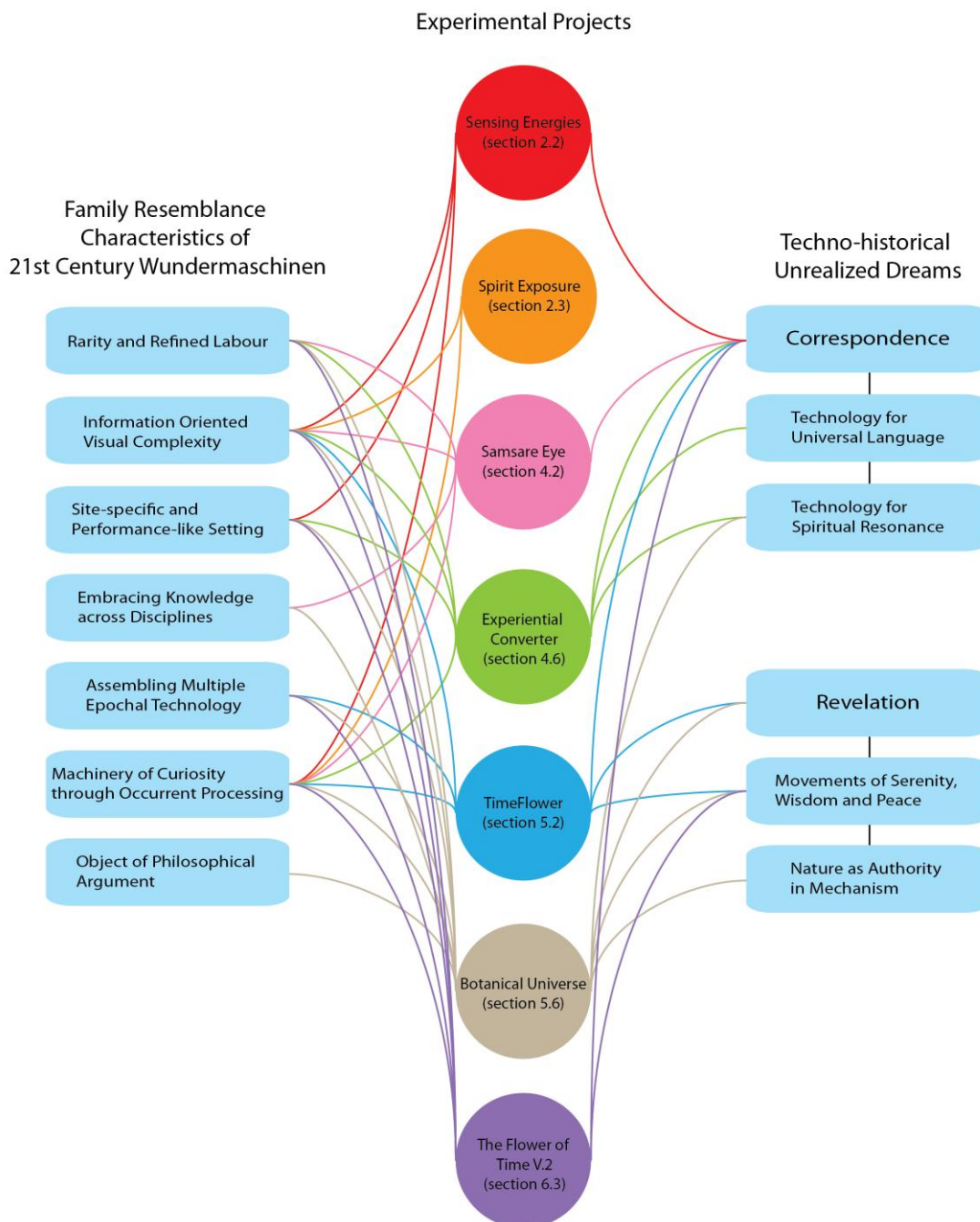


Figure 71 Summary picture: showing the annotations in relationship to the artefacts produced

6.2.2.4 Media research tendencies?

It is the media archaeological review (on canonical Wundermaschinen in section 3.3, correspondence media in section 4.3 and clock mechanisms in section 5.3) that reveals how the interplay of the imaginary and actual, the desired and realized, is constantly at work in the practice of human technology. The practice of contemporary media can be a creative way of doing media archaeology. This research suggests that media archaeology should be adopted as an artistic methodology in prototyping a 21st century Wundermaschine (see section 4.6.10). This tendency of media archaeology is a critique of technological progress. It suggests that media development is not to be considered linear progress, but a mixture of the imagined, desired, and realized. The future course of technological and media development then becomes contentious and unpredictable. My research widely supports Zielinski's paleontological view (Zielinski, 2006, p.5) of media history and suggests that human media had much more diversity in the past, and the current state of the media does not represent the best possible state (Zielinski, 2006, p.5). Uncovering the heterogeneity and multiplicity of historical media objects is thus advantageous for informing the design and discussion of contemporary artefacts. The media history is not a product of a predictable progress from primitive to complex apparatus. It is a resourceful network full of dreams, desires, secrets and faiths, some of which provide potential design attributes for contemporary artefact design.

6.3 Selected Implications

This practice-based research on Wundermaschinen has given rise to an abundance of issues, advances, lessons and speculative conclusions over its course. In this section, I will revisit the initial literature reviews and early discussion, and will give recommendations to other researchers.

6.3.1 *Revisiting Initial Literature Review and Discussions*

In Chapter 3, I reviewed historical machines of wonder and contemporary features of artefact prototyping to draw out some design implications for experimental practice. In section 3.3, a review of ‘Metaphorical Artefacts’ suggested that the machinery’s aesthetic criteria (of both mechanism and external craftsmanship) should be considered in close relation to metaphorical imaginings of the ultimate realm (e.g. divine life, authoritarian state and regularity) they were designed to illustrate. A review of ‘Mimetic Motions’ suggested that the machinery could embody a creative inquiry that aims to imply potential meanings for the essence of life and intelligence. A review of ‘Mechanisms of Illusion and Trickery’ informed us of the inseparable connection between technology and illusion. We should not therefore exclude magic from the development of modern technology, neither can we draw a clear boundary between illusion making and engineering.

In section 3.4, a review of emerging maker-culture revealed an ‘accurate, individualized and nomadic’ nature in contemporary computer-assisted DIY. A reflection on open source making reminded us of the ‘homogenisation of novelty’ in contemporary making and sharing communities. In order to go beyond such homogeneity, I analyzed the overlapping similarities between historical machines of wonder and contemporary features of artefact prototyping, and speculated seven family resemblance characteristics of 21st century Wundermaschinen (see section 3.5).

Further experimentations suggested two threads of Wundermaschine making: the Wundermaschinen of Correspondence (Chapter 4) and Wundermaschinen of Revelation (Chapter 5). The practice of Wundermaschinen of Correspondence reveals the dual nature of new media. That is, the ‘expressive’: new media as sensual, emotional and intellectual levers, and the ‘analytic’: new media that allows us to peer into worlds beyond our normal senses to

bring together patterns beyond our normal recognition (discussed in section 4.6.9). The practice of Wundermaschinen of Revelation suggests to contemporary artefact makers that they discard luxury and costly decorations, and instead focus on how new issues and thoughts could originate from the experimental assemblage of everyday electronics and materials. In addition, this research suggests an approach based on ‘divergent materialities’ by comparing contemporary with historical Wundermaschinen, which reflects on the simultaneously new-and-old, and the precious-and-defective nature of present technologies (discussed in section 5.6.8).

This study has been widely informed by contemporary maker-culture, computer-assisted DIY, media archaeology, and current issues in Human Computer Interaction (HCI). Therefore, I will feedback the following recommendations to these fields of research as my research contribution.

6.3.2 *Lessons for HCI Researchers*

This study examines 21st century Wundermaschine as an orientation for so-called “Third Wave HCI” (Bowers, 2012, p.68). Third Wave HCI suggests design research might build its own ‘limited rationality’ rather than fit standards of design theory uncomfortably. It is concerned with lived human experience, intimacy, pleasure and embodiment (Bowers, 2012, p.68). Arguing that people are playful creatures and most of our activities are less utilitarian, researchers like Gaver also suggest that we design for “ludic activities” (Gaver, 2006; Gaver et al, 2004; Gaver, Bowers, Boehner, Boucher, Cameron, Hauenstein, Jarvis & Pennington, 2013). That is, an activity motivated by curiosity, exploration, aesthetic appreciation and reflection rather than externally defined tasks. Ludic design aims to be engaging and thought-provoking, and to “offer a new perspective on how technology might fit into our everyday lives” (Gaver et al., 2004, p.899). Parallel to these non-utilitarian and ludic roles

technology can play, the design of Wundermaschinen specifically investigates how technology becomes artefacts of wonder – that is, artefacts of curiosity, complex sensory qualities, and multi-disciplinary knowledge.

More particularly, the many design choices I made, as I have described in the technical details of projects, were influenced by the cultural-historical investigation of past media and reflection from previous designs, rather than specific user problems or tasks. For example, *Experiential Converter V.1* (described in section 4.6) allowed the users to engage curiously and open-endedly with familiar art images in an alternative setting (visual-auditory correspondent). Such engagement between the user and the artefact was motivated by the audience members' curiosity about the image-to-sound converting process (or result), rather than defined by the desire to accomplish some utilitarian goal. *Experiential Converter V.1* suggests that while the form and technological details are important to how a design functions, more important are the values that it supports. It suggests that the design of lived human experience in technology can richly embody cultural and esoteric intention, and such experience can evoke further curiosity and discussion of how technology might be more 'aesthetic' in our lives. *Experiential Converter V.1* also suggests that the spiritual and esoteric domains, which are not commonly discussed in HCI research, should be more embraced. As Gaver, Blythe, Boucher, Jarvis, Bowers & Wright (2010)'s *Prayer Companion* has demonstrated how a computational device can support intimate spiritual activity, my research shows a slightly different intention. Namely, a human's capacity for the imaginative, spiritual and esoteric can be re-aroused through human-computer interaction, and it is particularly the way we process information that is critical to such interaction.

In addition, for HCI researchers, this practice-based research demonstrates how the unrealized dreams of technology are revealed and further adopted to optimize the interaction between the

artefact and its users. This research suggests that we should explore the deeper layers of motivation that inform the creation and the wider adoption of human technology. To grasp these rather hidden motives, it is necessary to excavate some of the seemingly irrational undercurrents that accompany much of the visible history, and thus to explore more deeply into the realm of the mythological and hidden. In summary, this research suggests that HCI researchers project their vision not only to solve future problems, but also to re-engage the past. They should embrace a paleontological view of human technological development, and so include greater diversity and heterogeneity in their design requirements. The result of such ‘design-as-media-archaeology’, as this research proposes, will be more thought-provoking and aesthetic potential for HCI researchers.

6.3.3 *Lessons for Media Archaeology*

The various methods of media archaeology have contributed to different stages of this research, especially in how they excavate techno-historical unrealized dreams for creative intervention. As I have contended in section 4.6.10, this approach to media archaeology is particularly significant as it reflects on, and provides practical examples of, ‘media archaeology as artistic methodology’ (Hertz & Parikka, 2012). It suggests how the aspects of wonder of emerging computer-assisted fabrication can be reformulated through an archaeological orientation. Since artefact making and media archaeology in this study are so interwoven and not easily separable, I believe there is a lesson for media archaeology. That is, this research proposes a coherent fusion of new media and media archaeology.

Media researchers mostly agree that media archaeology is a field of study that is varied and not a consistent whole. There is no general argument about either the principles or the terminology of media archaeology (Huhtamo & Parikka, 2011, p.2). However, researchers embracing this tendency often share a questioning attitude, or sometimes a critical attitude,

towards new media. Some allege that new media often “overhauls” past history (Mattelart, 2001; Gitelman & Pingree, 2003). Others assert that new media’s technical and deterministic tendencies create an amnesiac modernism that neglects historical issues and values. For example, French media scholar Armand Mattelart comments that the discourse of new information technology is part of the paradigm which legitimizes change and the new while ignoring everything but technical-driven features (Mattelart, 2001). Parikka (2011) also comments:

“... studies of new media often share a disregard for the past... the past has been considered to have little to contribute toward their untangling... The new media have been treated as an all-encompassing and timeless realm that can be explained from within.” (Huhtamo & Parikka, 2011, p.1)

As a process of creative research utilizing both media archaeology and new media practice, my research proposes a different perspective. It identifies that new media practice utilizing computational programming, information visualisation, sensor technology, digital hardware and digital fabrication can have significant implications for media archaeological work. For example, it was the sensor network that allowed *Botanical Universe* to engage with the canonical quality of metaphorical, divine, and the philosophical characteristics in historical Wundermaschinen. It was the data communicating mechanism (I2C and Open Sound Control) in *Experiential Converter* that allowed it to re-engage the esoteric idea of correspondence, which has occupied many European artefact makers’ minds since long ago. It was also the computer-assisted tools that more generally allowed the resurrection of the genre of ‘machines of wonder’, which is widely considered as only a category in the past. This research suggests that media archaeology as an approach to “find our way into the future” (Huhtamo & Parikka, 2011, p.10) should interweave with new media much more. New media does not necessarily overhaul or ignore historical issues and values. It allows media

archaeology to be more engaging, and achieve what it aims to do. As Kluitenberg suggests, media archaeology should study the imaginaries in action across different historical and discursive settings and contexts (Kluitenberg, 2011, p.49). As Parikka (2011) suggests, there should be no separation in media; instead, there is constant interchange. The past can be brought to the present, and the present to the past (Huhtamo & Parikka, 2011, p.15). My research shows how such orientation is achieved through a media study where new media and media archaeology each play a coherent role.

6.3.4 *Lessons for Maker-Culture*

In literature on maker-culture and open source, we see over-positive speculations. Writers like Chris Anderson (2012, 2010) claim that a new Industrial Revolution is coming:

“The beauty of the Web is that it democratized the tools both of invention and of production. Anyone with an idea for a service can turn it into a product with some software code.” (Anderson, 2012, p.7)

Others like Tanenbaum (2013) claim that computer-assisted DIY allows a form of “individual revolts against the hegemonic structures of mass production” (Tanenbaum et al., 2013, p.2609). These ideas of democratization often assert that the emerging maker movement has potential impacts on the social-political infrastructure, and forms a new “democratic material culture” (Tanenbaum et al., 2013, p.2611). There are also researchers who hope that open source “offer[s] new perspectives on emerging social relations and in so doing, start[s] to transform the role that the arts play in the world” (Catlow & Garrett, 2011).

However, as a practitioner/researcher of open source and maker tools, I realize the current maker-culture still largely relies on existing industrial infrastructure, and few hackers and tinkerers have access to the raw materials that are driving these practices. Only a few

initiatives attempt to address this problem, such as FairPhone (2015). For example, to keep the cost of the *Arduino* microcontroller accessible for the casual hobbyist, we need the mass production of electronic components. Such contradiction highlights how unprepared our current infrastructure is to accommodate this new Industrial Revolution, and how over-positive the contemporary makers might be. In response to this over-optimism, researchers like Hertz have started a more critical discussion in maker communities (Hertz, 2015). Some urged a rethinking of why we make in these communities, and others revealed the political economical problems of Maker Faires (Altman, 2012).

Based on my practice-based research, I would like to give some further recommendations. Firstly, I suggest that the makers be more aware of the ‘homogenisation of novelty’ (as I have discussed in section 3.4.2) in maker-culture. The Free and Open Source Software (FOSS) movement initialized by motivating people to participate. It allows individuals to use, study and change the software, and the source code is openly shared so that people can improve the design of the software (Free Software Foundation, 2009). Under the influence of FOSS movement, contemporary maker-culture is thus largely driven by open source software such as *Processing*, *Arduino* and *PureData*. However, as my research shows, making is a rich and complex process of learning. It shows how an individual utilizes tools, solves problems, expresses ideas and links his/her practice to a wider context in the space and time. In this view, adopting computational tools into making should never be limited to a given fast or cheap solution. An overabundance of public software that is free and convenient might lead to a reduction of the heterogeneity in those thought processes. As a more practical recommendation, I suggest that the makers who support the educational values of the open source community not only share their computer codes, but also share the ‘reality of making’. That is, errors, failures, compromises and unrealized dreams.

Secondly, the concepts and processes of software engineers (that steer the maker-culture) should not be mapped directly onto artistic production. Software engineers know when something has worked. However, my research shows the self-reflective and artist-audience-reciprocal process of Wundermaschine making. Artists often do not have a testing module for their creative productions. Neither do they know easily when their project has completed. This suggests that maker-culture's emphasis on networked, peer-led and shared learning might partly benefit a creative practice, but this will not be so without a critical view on such culture itself. This is because an artist's role, as this practice-based research has revealed, is evidently not to follow emerging methods of making. Rather, it is to identify critical and even provocative attributes toward these methods/processes for further experimentations. Accordingly, contemporary maker-culture can at best provide a mirror for reflection (on future technology and ways of making), but cannot raise a revolution for a new system or order.

6.3.5 *Lessons for Philosophical Thinking about Human-machine Relationship*

Researchers like Casper (1994) and Suchman (2007) have cautioned against interaction designers who adopt a cognitive science strategy. Such a strategy represents mental constructs, such as goals or plans, then stipulates the procedures by which those constructs are realized as action or recognized as the actor's intent. The specification of procedures for action, in turn, "has presupposed enumeration of the conditions under which a given action is appropriate" (Suchman, 2007, p.176). Such strategy thus treats the complex world of objects, artefacts, and other actors located in space and time as an "extraneous problem" (Suchman, 2007, p.177). In other words, the stipulated conditions, ready made and coupled to their associated actions, take the place of a lively, moment-by-moment assessment of the significance of particular circumstances. According to Suchman, such strategy results in very limited designs for human machine relationships:

“Today’s machines... rely on a fixed array of sensory inputs, mapped to a predetermined set of internal states and responses. The result is an asymmetry that substantially limits the scope of interaction between people and machines.”
(L.Suchman, 2007, p.179)

In response to such concerns, my research explores 21st century Wundermaschinen and allows us to see unanticipated observations and opportunities provided by a particular experimental setup (Suchman, 2007, p.185). For example, *Samsare Eye* (section 4.2) was initially developed as a body-immersive 3D visualisation utilizing the *Kinect* technology. The audience feedback then showed that it was the experimental setup toward a meditative and private space that allowed more observations and discussions around the idea of correspondence in natural philosophy. Further practice of *Experiential Converter* suggested more opportunities to explore this idea of new media as a dual instrument of live information transformation (discussed in section 4.6.9). As I have argued, the Wundermaschine’s aesthetics rely on this spirit of re-configurations: not to solve problems, but to ask questions; not prototypes of innovation, but provocation; not the embodiment of a solution, but an engagement of curiosity toward potential knowledge. This research thus exemplifies several human-machine interactions that escape the cognitive science strategy. In agreement with Viller, Bowers and Rodden (1999), my practices suggest that we must take the human-machine interface not as an a priori or self-evident boundary between bodies and machines but as a relation enacted in particular settings and one that shifts over time.

In addition, referring back to the discussion in section 4.6.9, the emerging human-machine relationship should be considered to have performative, multi-layered and aesthetic potential. The occurrent means of information representation brings a new quality of human-machine interaction: the simultaneously ‘expressive’ and ‘analytic’ character of such interaction can

take us to new philosophical discussions. It allows a high degree of control over some aspect of the sensory world, and at the same time maps aspects of the world that are outside our range or scale into regions within our sensorium, and within our perceptual, cognitive and affective ranges. Considering this potential field of philosophical discussion, Barad's (2003) argument toward a "performative metaphysics" provides a possible path:

"The universe is agential intra-activity in its becoming. The primary ontological units are not "things" but phenomena – dynamic topological re-configurings/ entanglements/ relationalities/ (re)articulations. ... This dynamism is agency. Agency is not an attribute but the ongoing re-configurings of the world". (Barad, 2003, p.818)

In other words, machines are considered agencies for material re-configuring/ discursive practices that produce material phenomena in their active process. Machines should be regarded as "material-discursive" (Barad, 2003) entities that help us understand ourselves. They are conceptual tools for human "self-examination" (Wolfe, 2004, p.241). This performative account, by adopting both aesthetic and analytic strategy, examines the machine as philosophical apparatus: how it embodies ethics, knowledge, hopes and fears, and specific values.

6.3.6 *Lessons for Spiritual Practices*

This research suggests an 'optimistic' view on technology and spirituality. As suggested by Bauwens (1996), an optimistic school of thought, as exemplified in the works of Georg Wilhelm Friedrich Hegel and Pierre Teilhard de Chardin, takes an evolutionary approach. These philosophers generally agree that there was a fall, at the creation of the Cosmos and our universe, when divine consciousness was lost in unconscious matter. But from that point on, there has been progress towards ever higher levels of complexity and consciousness

(Bauwens, 1996). This view considers technology to be one more step in the unfolding of mankind's consciousness.

Sharing this optimistic view, my literature review showed that late Middle Age European clockwork was seen as God's intervention bringing "divine regularity to the erratic flow of earthly existence" (Kluitenberg, 2011, p.49). Media practitioners /alchemists like Martin Howse have also demonstrated that the merging of man with technology could be seen as part of a larger mystical task within the universe. In Howse's view, we can now communicate with natural entities through electrical impulses and "return memory to the earth" (Howse, 2015) (as discussed in section 2.3.5). In the practice of *Samsara Eye*, I used spiritual symbols in Buddhism (e.g. Mandala) for focusing attention, and for meditation and trance induction. *Experiential Converter* showed how an esoteric idea of correspondence could be experienced through melodic sound. *Botanical Universe* presented an artefact of revelation, which created 'movement of serenity, wisdom and peace' (in section 5.6.5) and an ultimate realm of 'nature as authority' (in section 5.6.6). Its resonance with the idea of *Slow Computing* and conscientious consuming (in section 5.6.7) suggested the possibility of designing technology as a reflection on technological consumption. These all suggest the potential to infuse computational technology with human actions and opportunities for inducing spiritual experiences and cultivating conscious development.

In addition, one of the fundamental aims of spiritual practice has been to extend human identities, to overcome feelings of separateness from the rest of mankind, nature, and the Cosmos (Bauwens, 1996). In order to achieve this aim, a material basis and certain tools are needed. Emerging computational technology shows a return from cyberspace (as a parallel world to reality) to tangible computing, which encourages mankind's consciousness of new

relationships between entities in the universe. If not being over-positive, technology can thus be seen as a necessary adjunct to make improvements in consciousness possible.

6.4 Finalising Project: The Flower of Time V.2 (Jan – Mar 2016)

6.4.1 *Methodology*

As a finalising project, the making of *The Flower of Time V.2* aimed to display the outcome of this study as a physical artefact. Adopting a method of interdisciplinary approach to making, *The Flower of Time V.2* particularly explored how a responsive and unusual representation of time can engender wonder in the audience. The techniques learned in the course of this study were utilized to achieve this goal (see section 6.4.4 for technical detail). The work was presented in Culture Lab for audience feedback (section 6.4.5). Based on such feedback and reflection, future work of this research will be suggested in section 6.6.

6.4.2 *Aims and Developmental Context*

The exhibition of *The Flower of Time V.2* in *Loops-Layers-Lines* (an exhibition and performance event in Space 4, Culture Lab, Newcastle University in March 2016) (see Figure 72 and Appendix 9) was a material presentation of the outcome of this research.

The development of *The Flower of Time V.2* transformed this research's discussion of human-machine reconfiguration into a spatial and material artefact. As stated in methodology, the notion of artefact as “material thesis” (Seago & Dunne, 1999, p.16) is one in which the artefact itself becomes a physical embodiment of the concept, or outcome, the thesis is developing. *The Flower of Time V.2* aimed to explore the aesthetic experience in human-clock interaction by materializing several characteristics of the 21st century Wundermaschinen, which included ‘rarity and refined labour’ (section 3.5.1), ‘information-oriented visual

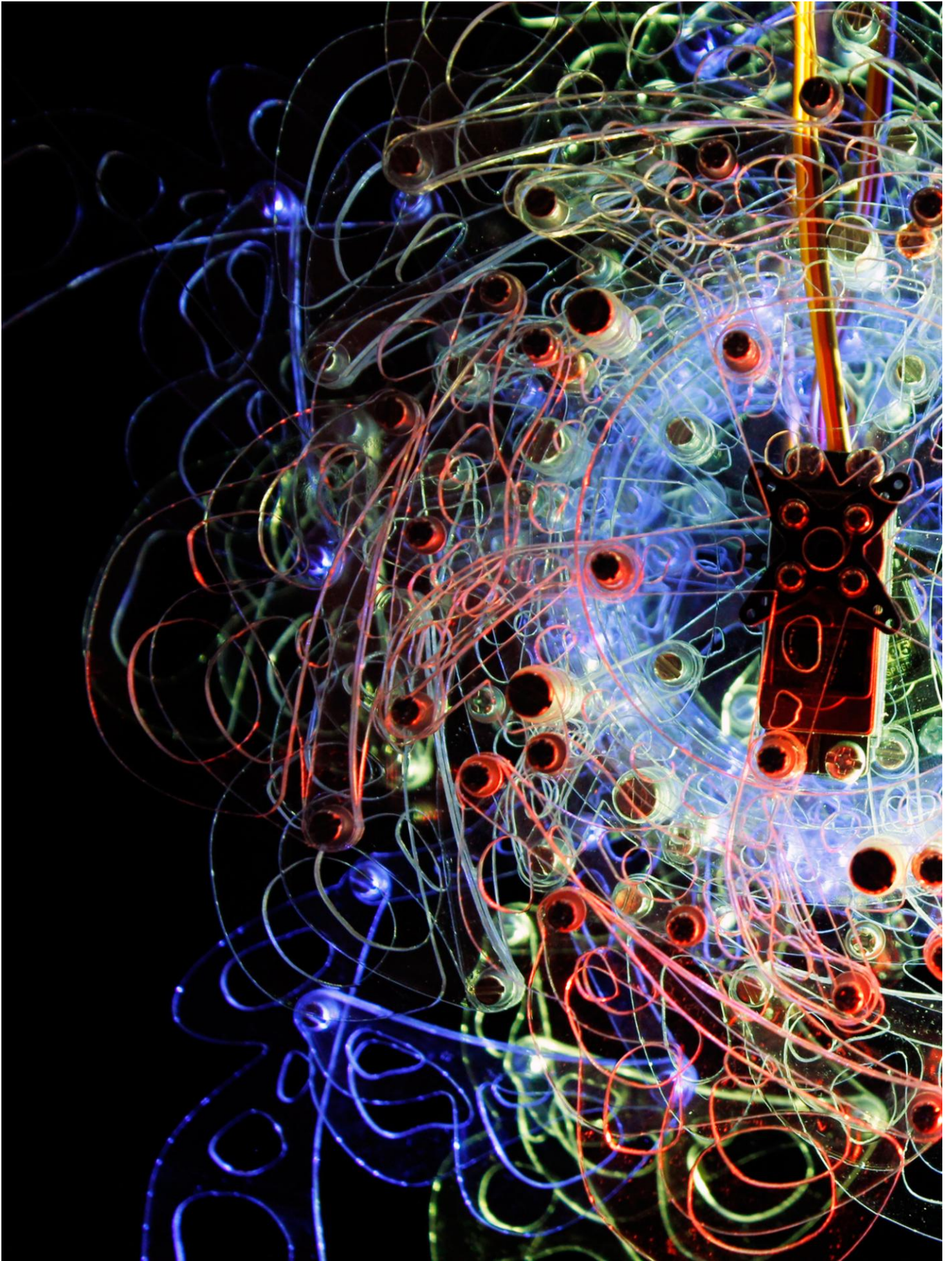
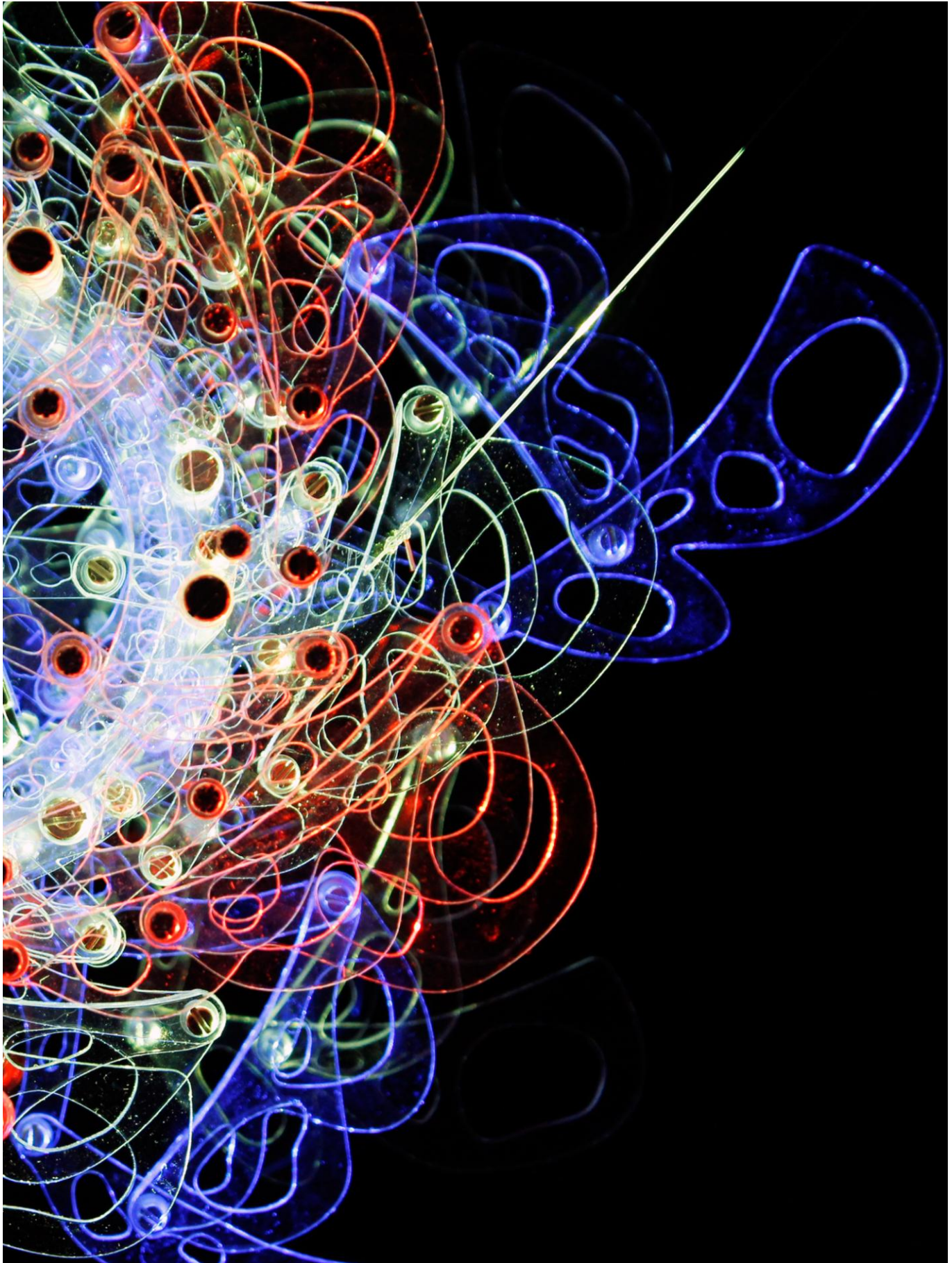


Figure 72 *The Flower of Time V.2* in Exhibition *Loops-Layers-Lines*



complexity’ (section 3.5.2) and ‘assembling multiple epochal technologies’ (section 3.5.5). It particularly demonstrated how a clock could transcend its utilitarian role and become a ‘mutually enveloping’ experience. What I mean by mutual enveloping is that *The Flower of Time V.2* embodied at the same time ‘precision’ (ticking and transforming according to the time readings) and ‘visual complexity’ (producing multi-layered visualisation for the viewers’ aesthetic appreciation).

6.4.3 ***Design, Implementation and Aesthetics***

The Flower of Time V.2 was a mechanical version of the previous work *TimeFlower* (2013), which explored the aesthetic potential in the visualisation of time. Assembled with *Arduino UNO* board, *Adafruit 16-Channel PWM Driver*, acrylic sheets, servomotors, screws, and fishing lines, the work was an information mapping mechanism that translated current time readings into correspondent pattern and colours. The mechanism design was intended to be compact and concise in space to provoke visual complexity. The overall mechanism was designed in *Illustrator*, manufactured in a laser cutter and assembled by hand (see Figure 73). Before completing the final working version, several testing versions had been made.

6.4.4 ***Technical Description***

The Flower of Time V.2 was an assemblage of four mechanical layers constructed from transparent acrylic sheets, which separately indicated the reading of second, minute, hour and day (see Figure 74). Each layer was actuated by a servomotor controlled by a main *Adafruit*

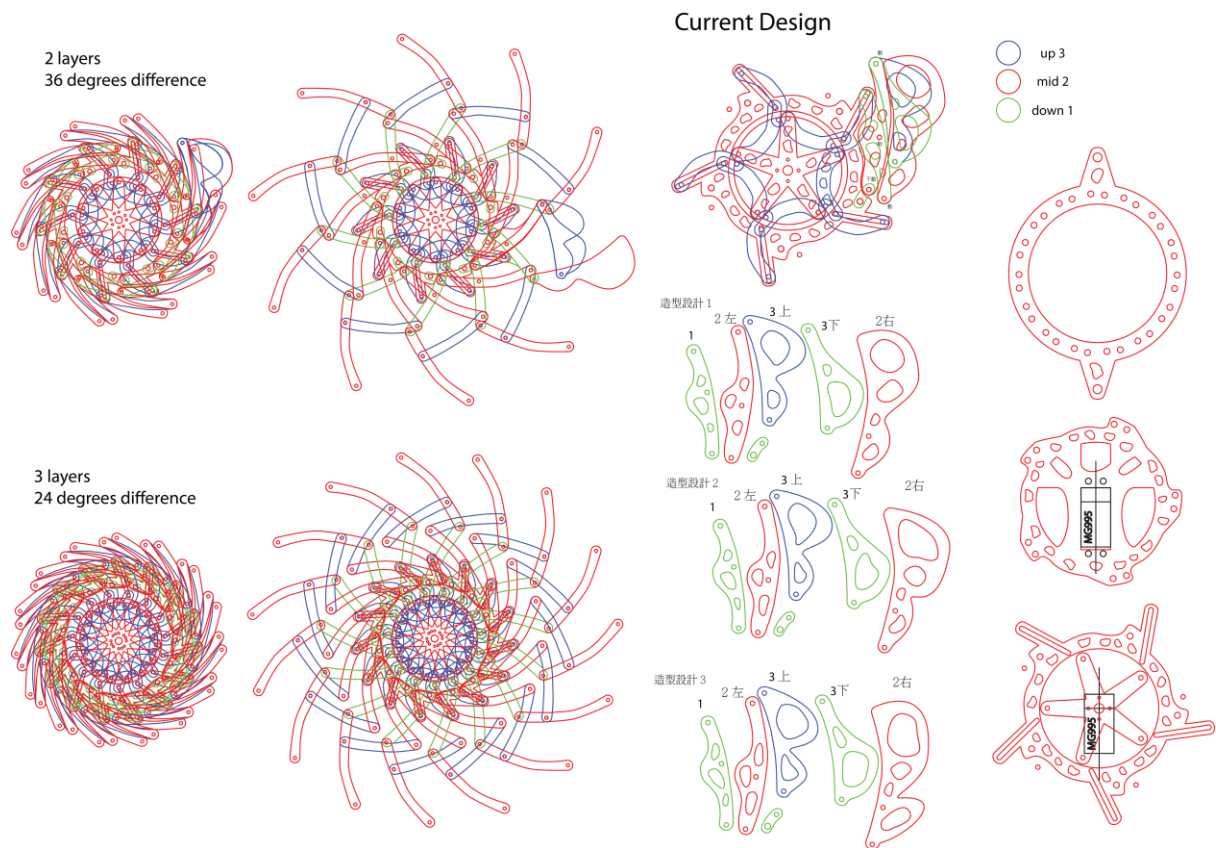


Figure 73 Designing of the mechanism of *The Flower of Time V.2* in Illustrator

16-Channel PWM Driver. The layer of second, being closest to the audience, ticked every second and could complete its circulation in a minute, while the farthest layer of day ticked once a day and could complete its circulation in a year. Every tick changed the size of the mechanism. In terms of the layer of second, the mechanical shape expanded outward from the minimum to the maximum as the seconds went from 0 to 30, and otherwise shrank back as it went from 30 to 59. This was achieved by mapping the time digits to a degree between 0 -180 for the servomotor. The same concept of circularity was applied to all four layers. In other words, in different to *TimeFlower* (2013) that had a repeatable 24-hour pattern (described in section 5.2.4), the mechanism of *The Flower of Time V.2* allowed it to perform each moment in a year with a unique representation. The same pattern will be visible at the same time each year.



Figure 74 The mechanical design of *The Flower of Time V.2* was an assemblage of four mechanical layers. The first layer on the left was the layer of second, then from left to right, the layer of minute, hour and day

In order to simulate a visualisation of the blossom of flower, each layer of mechanism was assembled with acrylic sheets that had been cut into different shapes of petals. After multiple tests, some random shapes were intentionally carved out of the acrylic petals to reduce their weight, since the whole mechanism worked smoother and had less friction by doing so.

In the exhibition, each layer also had a precise colour hue that was correspondent to the time readings. This was achieved through colour light projection from the side of mechanism. I mapped the time readings into colour hues according to their shared circularity. In terms of hours that went from 1 to 24, the colour hue changed gradually from red, through yellow, green, cyan, blue, magenta and back to red (see Figure 75 for the colour mapping scheme). The same mapping technique was applied to all four layers. Since the whole structure was

assembled with transparent acrylic, the audience could see through all colourful layers (see Figure 76 and Figure 77). Based on this mapping approach, the work represented each second in the year with a unique colour and formation.

In addition to the clock ticking mode, *The Flower of Time V.2* also had a performance mode that triggered every few minutes (see Figure 78). For example, when the digit of minute reading was 2, it performed a mode which the mechanism and colours moved/changed in pairs. In performance mode, the mechanism rhythmically and dynamically transformed its shape and colours. The performance mode lasted one minute before went back to clock ticking mode. Different performance mode indicated different minute readings.

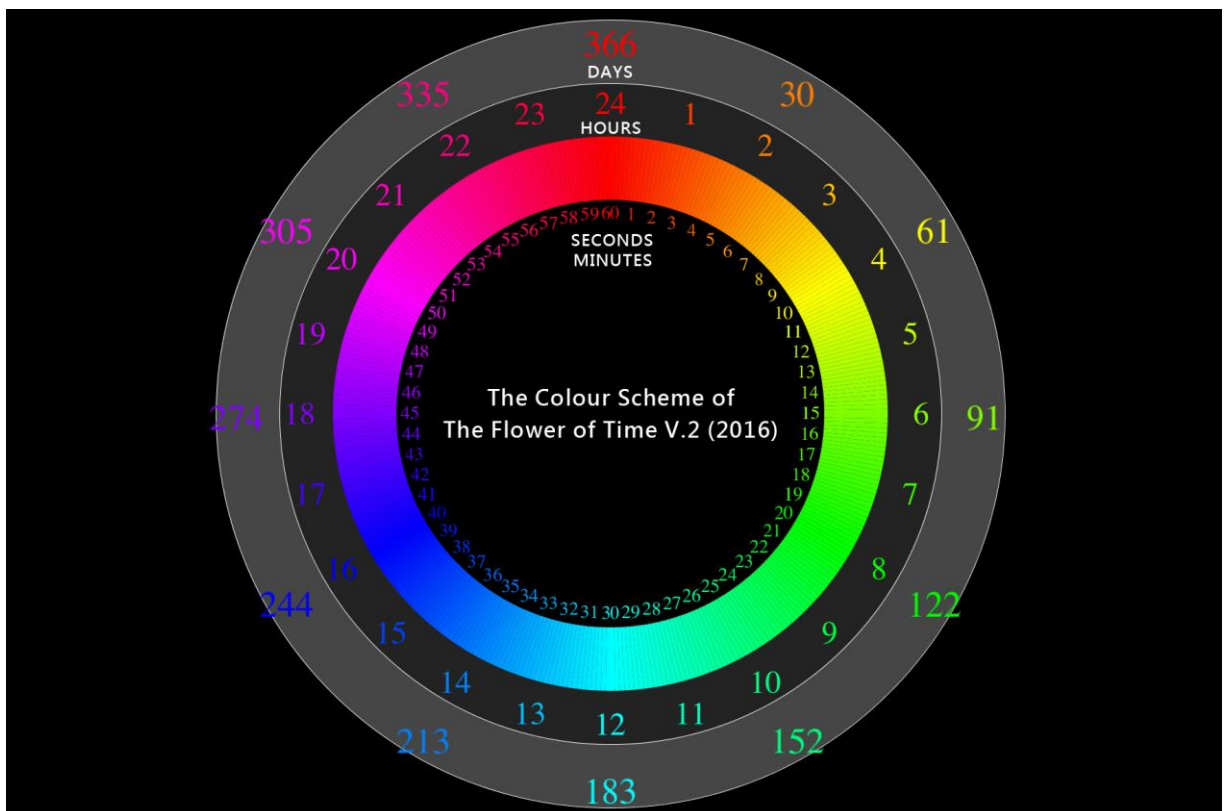


Figure 75 The colour mapping scheme of *The Flower of Time V.2*

6.4.5 *Audience Response and Self-reflection*

The Flower of Time V.2 received much audience feedback, especially on its coherence between concept and visual quality. Most audience firstly understood the work as a delicate piece of mechanism for visual experiment. Many came close to see the piece and stayed for quite a while. They seemed to enjoy the delicately transforming colours and shapes of the work, and expressed their surprise at how such a mechanism could be designed and manufactured. Coming to understand the work as a form of clock made the audience even more intrigued by the piece. For example, one of the male visitors commented on the work as “amazing! I can see this all day” after I explained to him the design context. This suggested *The Flower of Time V.2* embody a character of ‘machinery of curiosity through occurrent processing’ (section 3.5.6), which encouraged the audience to explore in detail. It was also an alternative form of clock that could arouse discussions of ‘reconfiguration of human-machine relationship’ (section 1.2.2). That is, a relationship of wonder, imagination, and even revelation. As a final presentation of this research toward 21st century Wundermaschinen, the rich audience feedback on this work inspired further practices and research beyond this study.

6.4.6 *New Knowledge Occurred in the Making*

The making for *The Flower of Time V.2* suggests that it is potential to construct a mechanism that is at the same time functional and visual attractive. Digital fabrication tools such as *Adobe Illustrator* and laser cutter can largely help create such design. Please see Appendix 16 for more details.

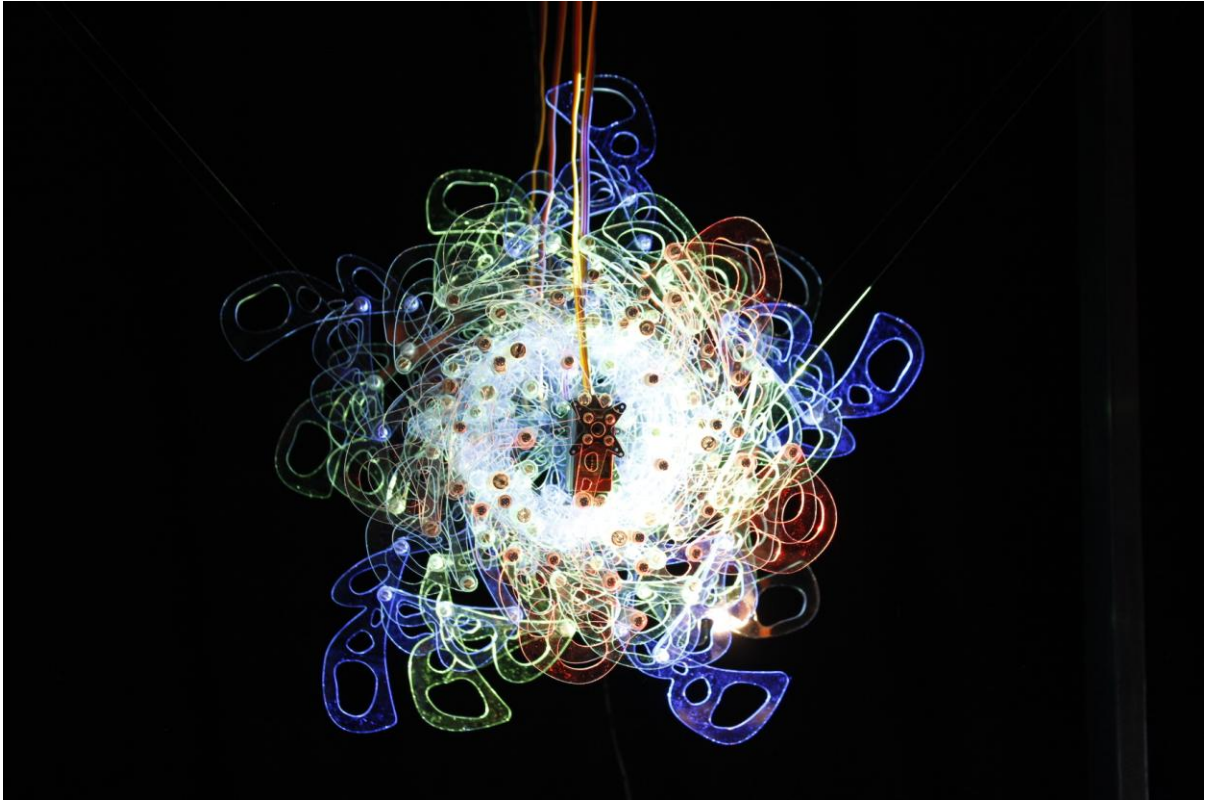


Figure 76 *The Flower of Time V.2* in Exhibition *Loops-Layers-Lines*

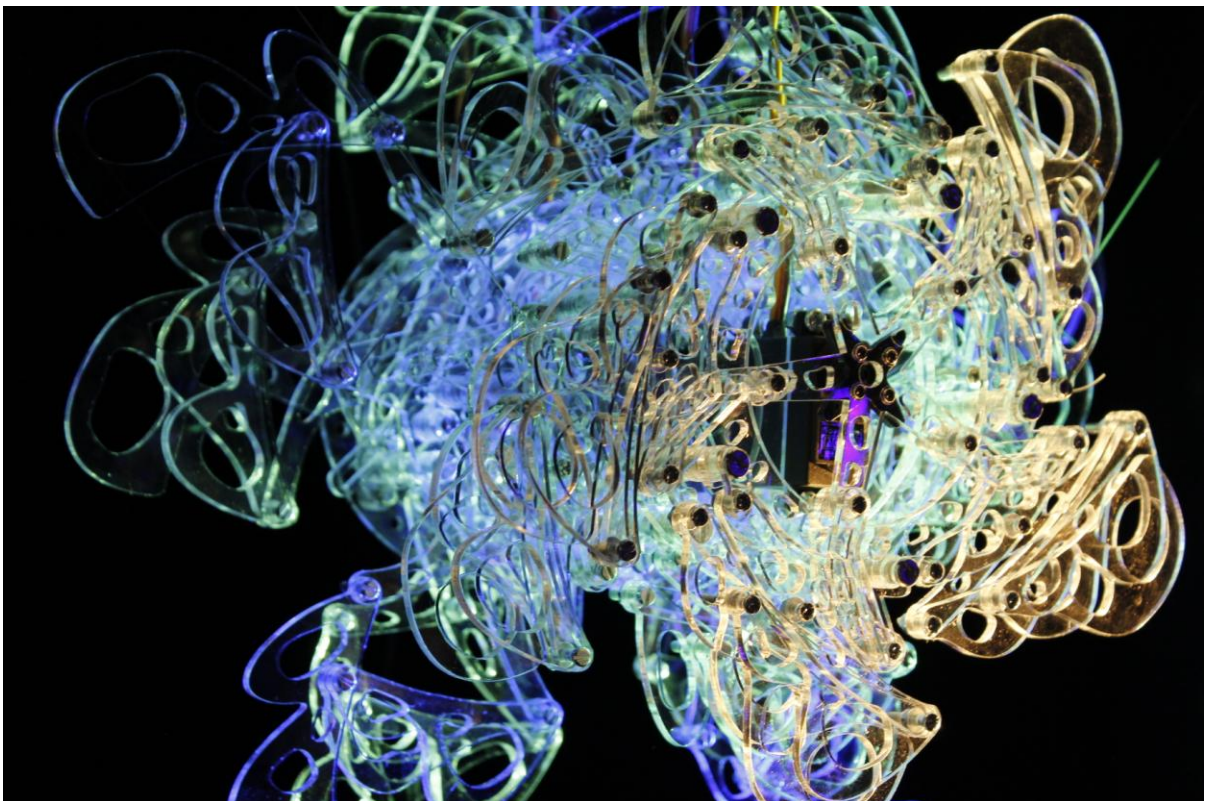


Figure 77 *The Flower of Time V.2* was assembled with transparent acrylic sheets. A colour light projection from the side of mechanism created accurate colour hues for each layer

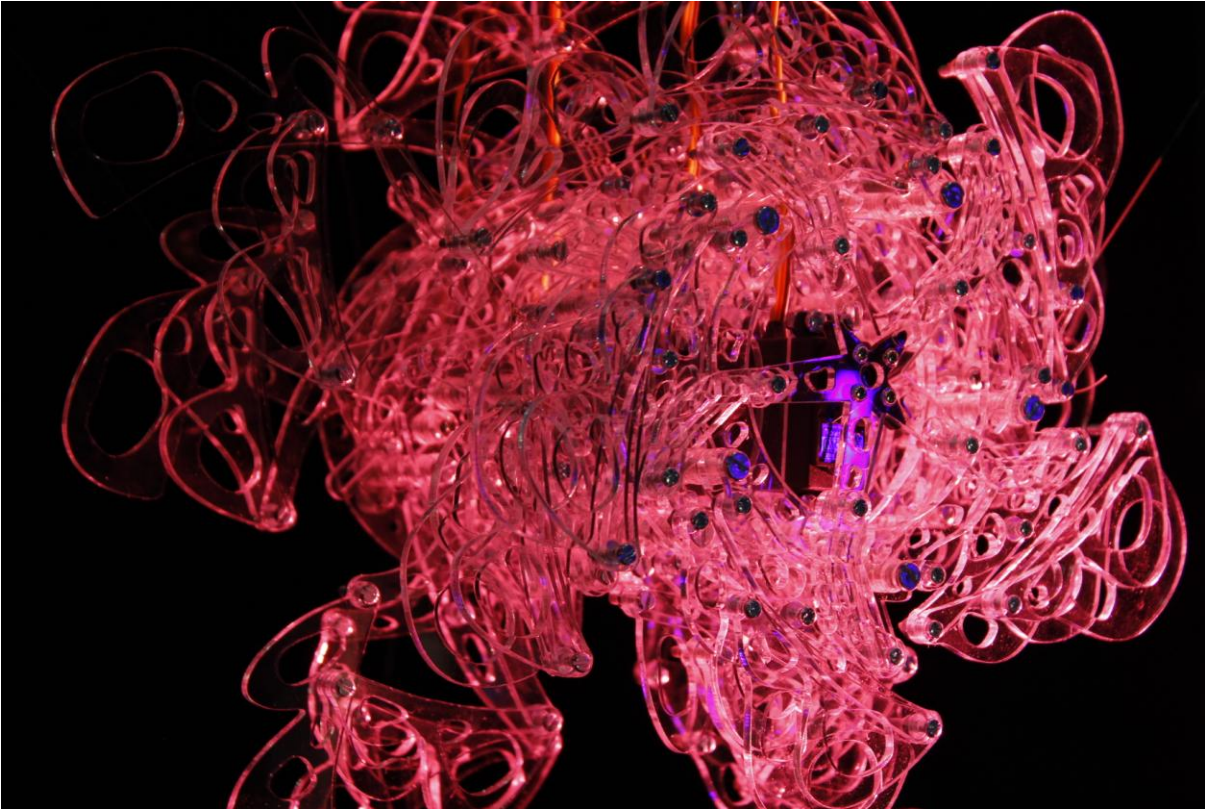


Figure 78 *The Flower of Time V.2* in performance mode (see main text for explanation)

6.5 Limitations of the Evaluation Methods of this Research

The evaluation method used in this research is a means of ‘reflective prototyping’ (section 1.5.4) mainly based on audience feedback and self-reflection. By presenting the artworks to the audience and discussing the work with them, this research gained much feedback on how to further develop the artwork, especially considering the related technical support, potential development, or the coherence to emerging issues.

However, it is reflected that there is a weak spot in how the artworks were exhibited and presented in this research. This weakness is caused by two factors. Firstly, the works were exhibited and presented mainly in Culture Lab, so that the audience members were mostly academics and other digital focus research students. This could very possibly limit the scope

of the audience feedback, as the audience often shared a similar logic with me – the artist/researcher. It was easy for me to discuss with other professionals the technical details of artworks and related researches. However, the diversity of audience feedback seemed to be lost. Not many critical perspectives were received from the audience in this process. The suggestions from the audience were mostly academic, rather than reflections from daily usage of technology. Secondly, I used inconsistent and unrecorded comments for further reflection in this research. This could be problematic. This study may easily ignore critical suggestions, as well as arrogantly select the feedback that well fits the research logic. The audience members may also not present all their thoughts about the work when I talk to them directly. The value that can be claimed from this means is therefore very limited.

In future work, I would like to devote more time on the analysis of audience experience. To understand how exactly the complexity and diversity of experiences a contemporary Wundermaschine creates should be considered critical. I would like to conduct user study on specific work with recorded interviews or questionnaires. I would also exhibit my artwork in various venues, for example, galleries, museums or maker fairs to gain feedback from various sources.

6.6 Future Work

6.6.1 *New Media as Dual Instrument*

In section 4.6.9, I argued that the techno-historical unrealized dreams of ‘correspondence’ are not limited to human body-sensory communications. Other relationships, known and unknown in the universe, carry potential for media experiments with sensor technologies. Historically originating from esotericism and natural theology, this notion of correspondence as searching for potential relations between entities is not an indulgent pre-scientific myth, or a naïve Spiritualism, but a creative potential criterion for contemporary artefact making. It

suggests that new media practitioners open up their curiosity toward various entities in the universe, across domains that traverse the contemporary/historical, material/phenomenal or aesthetic/scientific dualism.

This interest toward correspondence media leads to characteristic design aesthetics and cultural-historical investigations. It directs new media practice to be more performative and co-occurrent for live data representation. Such correspondence media have a dual character of ‘expressive and scientific’ (as contended in section 4.6.9) through which we can envision future media interventions that peer into new worlds and that return not simply numbers, images or sounds, but compositions directed at all our sensual and intellectual capacities. This instrument of dual character will benefit from artists’ ability to form aesthetic evaluations of interwoven and cross modal information, as well as scientists’ analytical perspectives. This tendency of new media as dual instrument suggests more collaboration between media art practitioners and scientific researchers, not merely to visualise data, but in order to challenge ideologies in the domains of art and science. In the future, I suggest that the information, which will be detected by various sensors and presented in numerous ways, can be meaningful as well as aesthetic.

6.6.2 *21st Century Wundermaschinen as Art Practice*

In keeping with the personal aims stated in section 1.1, this research has contributed to my own development as an artist/researcher working with a variety of material forms and concepts. In this research, I often confront situations in which I need to re-consider the prejudiced thoughts on the nature of art objects, which originate from previous experiences as a painter and sculptor. For example, with an initial aim of exploring how artistic intention could be merged with means of information visualisation and of seeing its ‘aesthetic potential’ (as described in section 1.2.1), I have gained many unexpected outcomes throughout the

course of study. The juxtaposition between contemporary individualized machine DIY and canonical Wundermaschinen in history revealed a more critical space for creative engagements.

This research thus serves to encourage further creative practice to escape from a conventional experience-oriented design/art method, and shift to a media archaeological approach in thinking and making. It suggests that machines, as well as other conventional artistic crafts and materials, should be understood as media of mimesis, expression, communication of emotion, discursivity, and other subtle qualities of human nature. This novel apprehension of the machine curiosity could be explored in an emerging branch of philosophy as Wundermaschine aesthetics.

Robert D. Romanyshyn (1989) discusses technology as “symptoms and dreams”, suggesting that:

“To attend to the cultural dream of technology, then, is to attend to the shadows and silences of technology... In this respect every dream is also a call to remember what would otherwise be forgotten on the surface of events and things.” (Romanyshyn, 1989, p.13)

In Romanyshyn’s words, creative media practitioners utilizing technology then play an appropriate role in engaging these ‘shadows and silences’ with an aesthetic motive. Reflecting Romanyshyn’s psychoanalytically informed idea that the dream speaks the language of images instead of the language of reason, the aesthetics of 21st century Wundermaschinen facilitate the re-imagination of technology in history, speculation toward future technology, and the re-engagement of unrealized dreams and hidden paths of human technological development. This idea of media practitioner as “dream catcher” coheres Ingold’s intriguing argument conceiving the relation between imagination and making:

“Artists, architects, composers and writers are likewise bent upon capturing the insights of an imagination always inclined to shoot off into the distance, and on bringing them back into the immediacy of material engagement. Like hunters, they too are dream catchers. Human endeavours, it seems, are forever poised between catching dreams and coaxing materials. In this tension, between the pull of hopes and dreams and the drag of material constraint, and not in any opposition between cognitive intellection and mechanical execution, lies the relation between design and making. It is precisely where the reach of the imagination meets the friction of materials, or where the forces of ambition rub up against the rough edges of the world, that human life is lived.” (Ingold, 2013, p.73).

Accordingly, my research demonstrates one of the potential ways that emerging technology can reflect back on its own history and generate the imaginary to direct human thoughts and makings. It outlines a future space of dreams, vision and fantasy where potential knowledge and disciplines can emerge.

Appendices I: Video Documentations of Artworks

Please see attached DVD for the following video files of documentation of projects conducted in this study.

1. 2012_Sensing_Energies.mp4 (described in section 2.2)
2. 2012-2013_Spirit_Exposure_V2.mp4 (described in section 2.3)
3. 2012-2013_Samsare_Eye.mp4 (described in section 4.2)
4. 2013-2014_Experiential_Converter_V1.mp4 (described in section 4.6)
5. 2013-2014_Experiential_Converter_V2.mp4 (described in section 4.6)
6. 2013_TimeFlower_V1.mp4 (described in section 5.2)
7. 2014_Botanical_Clock.mp4 (described in section 5.6)
8. 2014_Botanical_Universe_Exhibition.mp4 (described in section 5.6)
9. 2016_The_Flower_of_Time_V2.mp4 (described in section 6.4)

Appendices II: Developmental Process of Artworks

10. Sensing Energies:

The making of *Sensing Energies* firstly utilized a JSONObject library in *Processing* to store JSON data with multiple name/value pairs. I also used Gozorra library, which is a lightweight implementation of the *Stomp* specification. *Stomp* is a simple publish/subscribe messaging protocol and the Gozorra library includes both client and server implementations for Java. Utilizing these tools made it easy to communicate with a *Stomp* server via internet, and do things like publish, subscribe, receipt, and transaction. This technique helped retrieve the massive sensor data flow from the King's Gate Building. The following code is how I structure and map the sensor data:

```
class _Listener implements Listener {
    void message(Map m, String d) {
        // println(d);
        try {
            JSONObject data = new JSONObject(d);
            //println(data.getNames(data));
            //Temperature
            /* println(data.getNames(data));
            [0] "DeviceId"
            [1] "Type"
            [2] "Humidity"
            [3] "ParentAltAddress"
            [4] "Unsent"
            [5] "TimestampReceived"
            [6] "Battery"
            [7] "TimestampEstimated"
            [8] "SampleCount"
            [9] "Light"
            [10] "Version"
            [11] "Sequence"
            [12] "Samples"
            [13] "ParentAddress"
```

```

[14] "Temp"
*/

int deviceID=int( data.getString("DeviceId"));
float temperature;
int V =int( data.getString("Temp"));
if (V < 32768) {
    temperature  = ((V * 2500.0 / 1024.0) - 500.0) / 10.0;
}
else {
    temperature = (((16500.0 * (V & 0x7fff)) / 16384.0) - 4000.0) / 100.0;
}
//LIGHT
int L =int( data.getString("Light"));
float light  =  pow(10.0, L * 2.5 / 1024.0);
//BATTERY
int B =int( data.getString("Battery"));
float battery = B * 2.5 / 1024.0;
//HUMIDITY
int H =int( data.getString("Humidity"));
float humidity = H / 163.83;
//AUDIO AND PIR
JSONArray arrayD = data.getJSONArray("Samples");
float [] PIR = new float[arrayD.length()];
float [] audio = new float[arrayD.length()];
for (int i=0;i<arrayD.length();i++) {
    JSONArray locData = arrayD.getJSONArray(i);
    PIR[i]=  locData.getInt(1) * 2.5 / 1024.0;
    audio[i]= locData.getInt(2) * 2.5 / 1024.0;
}
//for (int i=0;i<arrayD.length();i++) {
Struct struct = new Struct(deviceID, temperature, light, battery, humidity, PIR, audio, 0);
// println("updating "+deviceID);

locations[ struct.id-4 ].update(struct);
}
catch(Exception e) {
}
}
}

```

The following code is to hold one reading from one sensor at any time:

```
class Struct {
    int id, sample_index;
    float temp_C, light_Lux, battery_V, humidity_percent;
    float [] pir_V, audio_V;
    Struct (int _id, float _temp_C, float _light_Lux, float _battery_V, float _humidity_percent, float []_pir_V,
float []_audio_V, int _sample_index) {
        id=_id;
        sample_index = _sample_index;
        temp_C= _temp_C;
        light_Lux = _light_Lux;
        battery_V = _battery_V;
        humidity_percent = _humidity_percent;
        pir_V =_pir_V;
        audio_V = _audio_V;
    }
    void update() {
    }
    int getId() {
        return id;
    }
    int getSampleIndex() {
        return sample_index;
    }
    float getTemp() {
        return temp_C;
    }
    float getLight() {
        return light_Lux;
    }
    float getBatt() {
        return battery_V;
    }
    float getHumidity() {
        return humidity_percent;
    }
}
```

```

float[] getPIR() {
    return pir_V;
}
float[] getAudio() {
    return audio_V;
}
}

```

After retrieving the data flow, I then started with several experiments on the juxtaposition of different colours and formations on the screen. Much time was spent in this process. The aim was to juxtapose various formations in a confined visualisation without confusing the audience. I found that by composing the visualisation with coloured squares, circles, triangles, lines and particles, I could achieve a better result. Coding in a *Processing* environment was quite advantageous to do this, as *Processing*'s object-oriented tabs (on top of the environment) could help the coder to remain a good structure in mind, and easily control all the behaviours of the objects generated. This largely helped the visual design of *Sensing Energies*. I suggest that future makers be familiar with the object-oriented structure in *Processing*, and solve coding problem based on this logic. This is because such object-oriented structure allows the coder to make subtle adjustments on each object created without influencing others.



The various objects claimed in *Sensing Energies* can be seen as ‘tabs’ in *Processing*. They can be edited without influencing other objects.

In addition, when all the sensor data was drawn on the screen, the visualisation of *Sensing Energies* became slow. It displayed fewer than 13 frames per second (fps). By controlling the numbers of the particles on the screen, this problem could be somehow solved. The strategy was to delete the oldest particle when the number of particles on the screen reaches 1000. The following code shows how I achieve this:

```

// Call Class display function
for (int i=0;i<balls.length;i++) {
    humidshow[i].display();
    balls[i].display();
}

// Call BPoint display function
for (int i=0;i<Bpoints.size();i++) {
    BPoint myBPoint2= (BPoint) Bpoints.get(i);
    myBPoint2.display();
    myBPoint2.move(random(1));
}

if (Bpoints.size())>=1000) {

```

```

    Bpoints.remove(0);
}

```

Finally, in the *W.I.P.* show, I realized that the visualisation of *Sensing Energies* could be understood differently depending on the outdoor environmental condition. For example, the flashing yellow circles (representing the light quantities) may suggest different meanings in the daytime and nighttime. In the day time, large flashing yellow circles may suggest abundant daylight. However, in the nighttime they may suggest over usage of light equipments and energy waste. In the future, how to help the audience understand these differences through sensor data and visualisation can be potential work.

11. Spirit Exposure

The design of *Spirit Exposure* started with experimenting and editing Daniel Shiffman's *Processing* example code 16-13: Simple Motion Detection (Shiffman, 2008b, p.353). This example uses the computer camera as a sensor to detect motion in the environment. It uses a colour comparing mechanism to detect the difference between two camera frames. Based on Shiffman's code, what I developed in *Spirit Exposure* was accumulating the motion quantities captured on the same image, so that it could save an image when the rendering was completed. The *Processing* code of *Spirit Exposure* is:

```

// Based on Learning Processing Daniel Shiffman Example 16-13: Simple motion detection
// Processing 2.0b6
// Ping-Yeh Li 2013
PFont font;
int sizeX=1280;
int sizeY=1024;
int[][] totalPix= new int[sizeX][sizeY];
import processing.video.*;
// Variable for capture device
Capture video;
// Previous Frame

```

```

PImage prevFrame;

// How different must a pixel be to be a "motion" pixel
float threshold = 50;
int exposureFrames= 3000;

void setup() {
    rectMode(CORNER);
    font = loadFont("ArialNarrow-48.vlw");
    background(255);
    size(sizeX, sizeY);
    video = new Capture(this, sizeX, sizeY);
    video.start();
    // Create an empty image the same size as the video
    prevFrame = createImage(video.width, video.height, RGB);
    //make totalPix all to be 0;
    for (int i=0; i<sizeX; i++) {
        for (int j=0;j<sizeY; j++) {
            totalPix[i][j]=0;
        }
    }
}

void draw() {
    // Capture video
    if (video.available()) {
        // Save previous frame for motion detection!!
        prevFrame.copy(video, 0, 0, video.width, video.height, 0, 0, video.width, video.height);
        // Before we read the new frame, we always save the previous frame for comparison!
        prevFrame.updatePixels();
        video.read();
    }
    loadPixels();
    video.loadPixels();
    prevFrame.loadPixels();
    // Begin loop to walk through every pixel
    for (int x = 0; x < video.width; x ++ ) {
        for (int y = 0; y < video.height; y ++ ) {
            int loc = x + y*video.width;          // Step 1, what is the 1D pixel location
            color current = video.pixels[loc];      // Step 2, what is the current color
            color previous = prevFrame.pixels[loc]; // Step 3, what is the previous color

```

```

// Step 4, compare colors (previous vs. current)
float r1 = red(current);
float g1 = green(current);
float b1 = blue(current);
float r2 = red(previous);
float g2 = green(previous);
float b2 = blue(previous);
float diff = dist(r1, g1, b1, r2, g2, b2);
// Step 5, How different are the colors?
// If the color at that pixel has changed, + 1 to it's int value.
if (diff > threshold) {
    if (totalPix[x][y] < 255) {
        totalPix[x][y] = totalPix[x][y] + 1;
    }
}
}
}

//updatePixels(); I dont have to show it
//if 10seconds passed, saveData
// println(frameCount);
if (frameCount == exposureFrames * 0.05) {
    drawing();
}
if (frameCount == exposureFrames * 0.1) {
    drawing();
}
if (frameCount == exposureFrames * 0.15) {
    drawing();
}
if (frameCount == exposureFrames * 0.2) {
    drawing();
}
if (frameCount == exposureFrames * 0.25) {
    drawing();
}
if (frameCount == exposureFrames * 0.3) {
    drawing();
}
if (frameCount == exposureFrames * 0.35) {
    drawing();
}

```

```

    }
    if (frameCount==exposureFrames*0.4) {
        drawing();
    }
    if (frameCount==exposureFrames*0.45) {
        drawing();
    }
    if (frameCount==exposureFrames*0.5) {
        drawing();
    }
    if (frameCount==exposureFrames*0.55) {
        drawing();
    }
    if (frameCount==exposureFrames*0.6) {
        drawing();
    }
    if (frameCount==exposureFrames*0.65) {
        drawing();
    }
    if (frameCount==exposureFrames*0.7) {
        drawing();
    }
    if (frameCount==exposureFrames*0.75) {
        drawing();
    }
    if (frameCount==exposureFrames*0.8) {
        drawing();
    }
    if (frameCount==exposureFrames*0.85) {
        drawing();
    }
    if (frameCount==exposureFrames*0.9) {
        drawing();
    }
    if (frameCount==exposureFrames*0.95) {
        drawing();
    }
    if (frameCount==exposureFrames) {
        saveData();
        drawing();
    }

```

```

    save("MotionCapture/005.png");
    exit();
}
if (mousePressed) {
    saveData();
    drawing();
    save("MotionCapture/005.png");
    exit();
}
noStroke();
// fill(255);
fill(200);
stroke(250);
strokeWeight(5);
rect(0, 0, width*0.4, height*0.05);
fill(250);
float rectWidth;
rectWidth= map(frameCount, 0, exposureFrames, 0, width*0.4);
rect(0, 0, rectWidth, height*0.05);
fill(50);
textFont(font, 48);
text("Exposed Frames= "+ frameCount, 20, 40);
}
void saveData() {
    // For each pixel make one String to be saved
    String[] data = new String[sizeX*sizeY];
    for (int x=0; x<sizeX; x++) {
        for (int y=0; y<sizeY; y++) {
            data[x+(y*sizeX)] = x + " " + y + " " + Integer.toString(totalPix[x][y]);
            // print(totalPix[x][y] + " ");
        }
    }
    saveStrings("data/data011.txt", data);
    //exit();
}
void drawing() {
    for (int x = 0; x < video.width; x ++ ) {
        for (int y = 0; y < video.height; y ++ ) {
            // int loc = x + y*video.width;
            // color c = color(totalPix[x][y]);

```

```

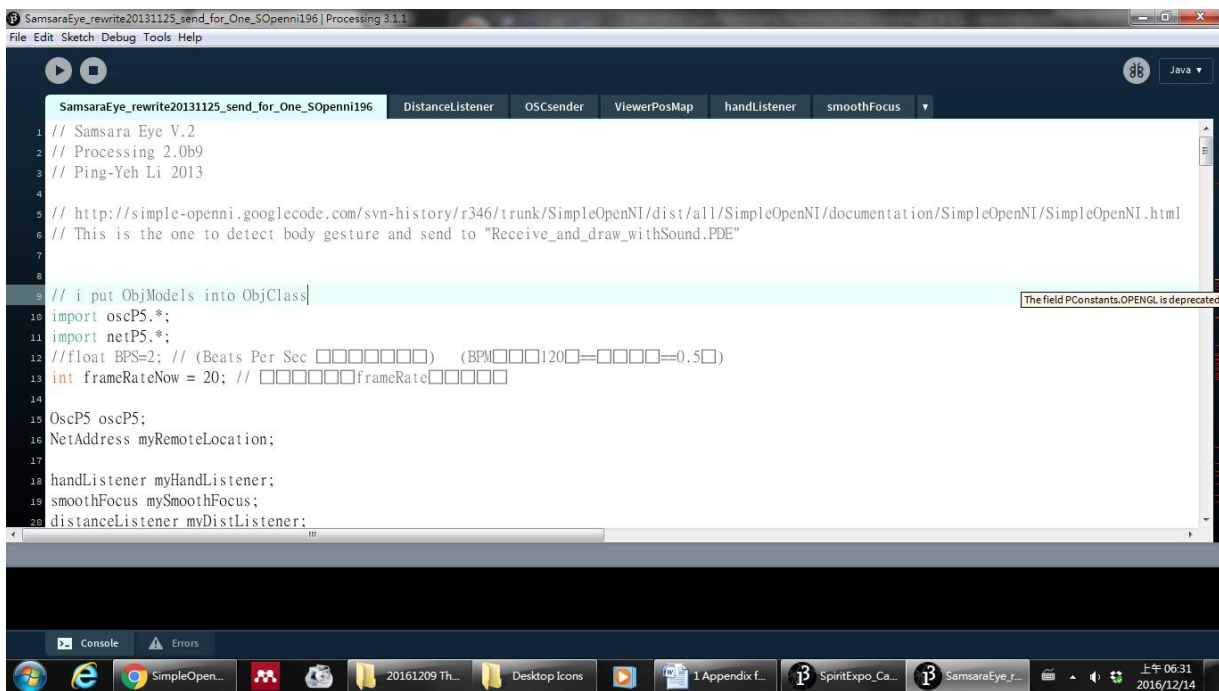
pixels[x+(y*sizeX)]=color(totalPix[x][y]);
// video.pixels[x+(y*sizeY)].g1=Integer.toString(totalPix[x][y]);
// video.pixels[x+(y*sizeY)].b1=Integer.toString(totalPix[x][y]);
// data[x+(y*sizeY)] = x + " " + y + " " + Integer.toString(totalPix[x][y]);
}
}
updatePixels();
// save("001.png");
}

```

As the above code shows, the ‘drawing()’ mechanism is for the coder to clearly see the rendering process in every few seconds. By editing the ‘float threshold’, *Spirit Exposure* can create different visual effects. I encourage future makers to play with a few variables in this code to produce various results. The threshold should be edited in response to different environmental conditions. For example, in the morning, the threshold can be adjusted higher than 50 so that more subtle results can be seen with longer exposure time. The making of *Spirit Exposure* realized how potential it is to play and experiment with the example codes provided by the *Processing* community. This suggests that for artists and designers potential qualities can be achieved in the process of simple copy-and-paste in an Open Source community.

12. Samsare Eye

The development of *Samsare Eye* started with experiments of the SimpleOpenNI library. This library can help the maker/artist easily connect the *Kinect* sensor to *Processing*. In the following screenshot of the *Processing* code of *Samsare Eye*, I created object of ‘DistanceListener’, ‘OSCsender’, ‘ViewerPosMap’, ‘handListener’ and ‘smoothFocus’. This object-oriented programming skill was learned through the development of *Sensing Energies*. It suggests that by claiming different objects and managing them in different ‘tabs’ in *Processing*, I can easily control their behavior without influencing others.



For example, the ‘DistanceListener’ can detect the distance between any two body parts with an average calculation to make the visualisation more smoothly:

```
class distanceListener {
    float[] distance;
    float distanceNow;
    float smoothDist;
}

distanceListener() {
    distance = new float[6];
    for (int i = 0; i < distance.length; i++) {
        distance[i] = 0;
    }
}

float listen(float distance_) {
    distanceNow = distance_;
    for (int i = 0; i < distance.length-1; i++) {
        distance[i] = distance[i+1];
    }
    distance[distance.length-1] = distanceNow;
}
```



```

smoothDist=0;
for (int i = 0; i < distance.length; i ++ ) {
    smoothDist+= distance[i];
}
smoothDist= smoothDist/6;
//smoothDist= (distance[0]+distance[3]+distance[distance.length-1])/3;
return(smoothDist);
}
}

```

The ‘OSCsender’ is an object that I created to send OSC data to *Puredata* to create sound:

```

class OSCsender {
    float userIDOSC;
    float xPos;
    float yPos;
    float zPos;
    float speed;
    float handDistOSC;
    float eRadius=30;
    int dice;
    boolean plzSend= true;
    float headDirectionOSC;
    OSCsender() {
    }
    void sendOSC_0() {
        if (currentTime- passedTime > 1500) {
            dice= int(random(5));
            plzSend= !plzSend;
            passedTime = millis();
        }
        if (plzSend== true) {
            if ( dice == 0) {
                OscMessage myMessage = new OscMessage("/position");
                myMessage.add(0.0); //1-5
                myMessage.add(220.0);
                myMessage.add(190.0);
                myMessage.add(3000.0);
            }
        }
    }
}

```

```

myMessage.add(400.0);
myMessage.add(0.0);
myMessage.add(0.1);
myMessage.add(0.0);
oscP5.send(myMessage, myRemoteLocation);
textFont(font, 28*scaleSize);
fill(200);
text("No Control - random 0", width*0.05, height*0.21);
}
if ( dice == 1) {
  OscMessage myMessage = new OscMessage("/position");
  myMessage.add(0.0); //1-5
  myMessage.add(530.0);
  myMessage.add(440.0);
  myMessage.add(1500.0);
  myMessage.add(300.0);
  myMessage.add(0.0);
  myMessage.add(-0.1);
  myMessage.add(0.0);
  oscP5.send(myMessage, myRemoteLocation);
  textFont(font, 28*scaleSize);
  fill(200);
  text("No Control - random 1", width*0.05, height*0.21);
}
if ( dice == 2) {
  OscMessage myMessage = new OscMessage("/position");
  myMessage.add(0.0); //1-5
  myMessage.add(120.0);
  myMessage.add(400.0);
  myMessage.add(1000.0);
  myMessage.add(600.0);
  myMessage.add(0.0);
  myMessage.add(0.3);
  myMessage.add(0.0);
  oscP5.send(myMessage, myRemoteLocation);
  textFont(font, 28*scaleSize);
  fill(200);
  text("No Control - random 2", width*0.05, height*0.21);
}
if ( dice == 3) {

```

```

OscMessage myMessage = new OscMessage("/position");
myMessage.add(0.0); //1-5
myMessage.add(600.0);
myMessage.add(240.0);
myMessage.add(1500.0);
myMessage.add(500.0);
myMessage.add(0.0);
myMessage.add(-0.3);
myMessage.add(0.0);
oscP5.send(myMessage, myRemoteLocation);
textFont(font, 28*scaleSize);
fill(200);
text("No Control - random 3", width*0.05, height*0.21);
}
if ( dice == 4) {
OscMessage myMessage = new OscMessage("/position");
myMessage.add(0.0); //1-5
myMessage.add(320.0);
myMessage.add(460.0);
myMessage.add(700.0);
myMessage.add(500.0);
myMessage.add(0.0);
myMessage.add(0.2);
myMessage.add(0.0);
oscP5.send(myMessage, myRemoteLocation);
textFont(font, 28*scaleSize);
fill(200);
text("No Control - random 4", width*0.05, height*0.21);
}
}
}

```

```

void sendOSC_1(float userID_, float x_, float y_, float z_, float handDist_, float speed_, float headDirection_,
float headForward_) {
  userIDOSC= userID_; //0
  xPos= x_; // 0-640
  yPos= y_; // 0-480
  zPos= z_;
  handDistOSC= handDist_;
  speed=speed_;

```

```

    headDirectionOSC= headDirection_;
    headForward=headForward_;
    OscMessage myMessage = new OscMessage("/position");
    myMessage.add(userIDOSC); //0
    myMessage.add(xPos);
    myMessage.add(yPos);
    myMessage.add(zPos);
    myMessage.add(handDistOSC);
    myMessage.add(speed);
    myMessage.add(headDirectionOSC);
    myMessage.add(headForward);

    oscP5.send(myMessage, myRemoteLocation);
    // text("1 Viewer!!", width*0.45, height*0.07);
    textFont(font, 28*scaleSize);
    text("SendingOSC", width*0.3, height*0.07);
}
}

```

The ‘ViewerPosMap’ is an object to draw the actual position of viewer from a top view. This helped understand what was actually going on before the *Kinect* sensor:

```

class ViewerPosMap {
    float userID;
    float xPos;
    float zPos;
    float volume; // for map
    float eRadius=30;
    // some ints for the map
    int mapHeight=8;
    int mapWidth=5;
    int middleRectX= 1;
    int middleRectY= 1;
    int middleRectWidth = 3;
    int middleRectHeight = 6;
    int smallRectX = 2;
    int smallRectY = 3;
    int smallRectWidth = 1;
}

```

```

int smallRectHeight= 2;
float focusX;
float focusY;

void display() {
    colorMode(RGB, 255);
    stroke(200);
    strokeWeight(5);
    rectMode(CORNER);
    // draw Kinect
    fill(100);
    rect(width*0.55+((width*0.4)/mapWidth)*1.5, height*0.02, width*0.15, height*0.03, 5);
    // draw big rect
    rect(width*0.55, height*0.1, width*0.4, height*0.8, 5);
    // draw middle rect
    fill(120, 150, 100);
    rect(width*0.55+((width*0.4)/mapWidth)*middleRectX,
height*0.1+((height*0.8)/mapHeight)*middleRectY, ((width*0.4)/mapWidth)*middleRectWidth,
((height*0.8)/mapHeight)*middleRectHeight);
    textFont(font, 26);
    fill(255);
    // draw small rect
    fill(50, 200, 0);
    rect(width*0.55+((width*0.4)/mapWidth)*smallRectX, height*0.1+((height*0.8)/mapHeight)*smallRectY,
((width*0.4)/mapWidth)*smallRectWidth, ((height*0.8)/mapHeight)*smallRectHeight);
    fill(255);
    // draw the white lines
    stroke(200);
    for (int i=1;i<mapHeight;i++) {
        line(width*0.55, height*0.1+((height*0.8)/mapHeight)*i, width*0.55+width*0.4,
height*0.1+((height*0.8)/mapHeight)*i);
    }
    for (int i=1;i<mapWidth;i++) {
        line(width*0.55+((width*0.4)/mapWidth)*i, height*0.1, width*0.55+((width*0.4)/mapWidth)*i,
height*0.1+height*0.8);
    }
    textFont(font, 20*scaleSize);
    text("z= 1500", width*0.7, height*0.09);
    text("z= 4200", width*0.7, height*0.95);
    text("x= 40", width*0.56, height*0.5);

```

```

    text("x= 600", width*0.88, height*0.5);
}

void displayViewers(float userID_, float x_, float z_) {
    colorMode(HSB, 255);
    userID= userID_; //0-4
    // map the viewers into my map
    xPos= int(map(x_, 40, 600, width*0.55, width*0.55+width*0.4));
    zPos= int(map(z_, 1500, 4200, height*0.1, height*0.1+height*0.8));
    if (xPos>width*0.55 && xPos<width*0.95 && zPos >height*0.1 && zPos< height*0.9) {
        ellipseMode(CENTER);
        float a = map(eRadius, 30, 100, 180, 255);
        fill(30+(userID)*30, 255, 255, a);
        noStroke();
        ellipse(xPos, zPos, eRadius, eRadius);
        fill(30+(userID)*30, 255, 255, a);
        text("user "+ (userID), xPos+30, zPos);
        noFill();
    }
    if (frameCount%(frameRateNow/2)==0) { // if it's sending OSC to Puredata,
        eRadius= eRadius+50; // make the ellipese bigger
    }
    eRadius*= 0.9;
    if ( eRadius < 30 ) eRadius = 30;
}

void displayFocus(float userID_, float x_, float z_) {
    userID= userID_; //0-4
    focusX= map(x_, 40, 600, width*0.55, width*0.55+width*0.4);
    focusY= map(z_, 1500, 4200, height*0.1, height*0.1+height*0.8);
    colorMode(RGB, 255);
    fill(255, 0, 0);
    noStroke();
    ellipseMode(CENTER);
    ellipse(focusX, focusY, 20, 20);
    text("Focus"+ userID, focusX+30, focusY+20);
    noFill();
}
}

```

As I have suggested earlier, this object-oriented programming skill is proven to help build a clear structure of interaction and visual design. I know where to find problem in my code more easily. In the making of *Samsare Eye*, this insight is further confirmed. For example, a problem about sound feedback can be found either in the 'OSCsender', or in the main frame of code. The 'ViewerPosMap' is a good debugging tool when the visualisation appears strangely. I can see whether the viewer is out of the interaction zone or whether the viewer's body parts are correctly detected. This experience of object-oriented coding in the making of *Samsare Eye* suggests future maker/artist to build a clear structure and function before designing creative artwork.

13. Experiential Converter

The development of *Experiential Converter* was a combination of a complex process. Firstly, this project started with an idea of enriching our experience of an object/image by an analytical approach in digital technology. Therefore, a technique of analyzing the colour information of an image was adopted. I wrote this software in *Processing* that could calculate an image's colour information and map it onto a colour wheel:

```
// change the image into "index color" =256 colors before using here
// image can be any size
// Make an ArrayList of colors
ArrayList myColors = new ArrayList();
import java.util.ArrayList;
import java.util.Collections;
import java.util.List;
PImage myPic;
int sizeX=600;
int sizeY=1000;
int k=0;
float startAngle=0;
float endAngle=0;
```

```

void setup() {
    // Each object in the ArrayList should have two values/fields
    aColorObject tempObject = new aColorObject(color(255, 5, 5), (int)1);
    myColors.add(tempObject);
    size(600, 900);
    background(255);
    smooth();
    myPic = loadImage("EightGods_indexed.png");
    image(myPic, 0, 0, 600, 400);
    // for each pixel, check every item in the list for a color match
    for (int i=0;i<myPic.pixels.length;i++) {
        // I need a boolean "flag" here to tell me the result of below
        boolean foundColorMatch = false;
        for (int j=0;j<myColors.size();j++) {
            aColorObject cc = (aColorObject) myColors.get(j);
            // if there is a color match
            if (color(myPic.pixels[i])==cc.c) {
                //increment "count"
                cc.count=cc.count+1;
                foundColorMatch = true;
            }
        }
        // if there is no match, before the for loop start again, increment one new color
        if (!foundColorMatch) {
            myColors.add(new aColorObject(color(myPic.pixels[i]), (int)1));
        }
    }
    myColors.remove(0); // remove the tempObject
    println("num of colors= " + myColors.size());
    println("pixelsLength= " + myPic.pixels.length);
    //sort the list
    Collections.sort(myColors);
    for (int i=0; i<myColors.size();i++) {
        noStroke();
        aColorObject cc = (aColorObject)myColors.get(i);
        println(cc.count);
        // Put "360.0" instead of "360" is important! To make it a float
        float thisAngle= cc.count*(360.0/(myPic.pixels.length));
        float endAngle= startAngle+thisAngle;
    }
}

```



```

        // draw the arcs
        fill(cc.c);
        // if (cc.count > 100) {
        arc(width*0.5, height*0.7, sizeX, sizeX, radians(startAngle), radians(endAngle), PIE);
        // }

        startAngle= endAngle;
    }

    // Draw a circle in the middle (alternative)
    /*
    fill(0);
    noStroke();
    ellipse(width*0.5, height*0.7, 200, 200);
    */

    save("images/"+ "EightGods_index_sorted_by_count.png");
}

public class aColorObject implements Comparable<aColorObject> {
    // remember the int is a primitive, Integer is an object
    color c;
    Integer count;
    Integer R;
    Integer G;
    Integer B;
    // Each object in the ArrayList should have two values/fields
    aColorObject(color _c, Integer _count) {
        c=_c;
        count=_count;
        R= int(red(c));
        G= int(green(c));
        B= int(blue(c));
    }
    public int compareTo(aColorObject other)
    {
        return count.compareTo(other.count);
    }
}

```

Then, I constructed the *Colour Collector*. I used stepper motor, rgb led, LCD screen and *Arduino* UNO and develop the following code that can detect colours on the colour wheel (see main text for more detail):

```
////////////////////////////////////
// Color Collector //
////////////////////////////////////

// LED 1st pin: Red, 2nd Pin(look in the LED the flat one):GND, 3rd pin:Blue, 4thpin: Green
int sensorRedPin = 2; // connect with 1st
int sensorGreenPin = 3; // connect with 4th
int sensorBluePin = 4; // connect with 3rd

////////////////////////////////////
// LCD 1602A Connection //
////////////////////////////////////

/*
  VSS --> GND    VDD --> 5V    A --> 5V    K --> GND    V0 --> middle pin of potmeter    RS --> 7    RW
-->GND    E --> 8    D4 --> 9    D5 --> 10    D6 --> 11    D7 --> 12
*/

////////////////////////////////////
// Stepper motor 28BYJ48 Connection //
////////////////////////////////////

/*
  Blue    - 28BYJ48 pin 1 --> 30    Pink    - 28BYJ48 pin 2 --> 31
  Yellow - 28BYJ48 pin 3 --> 32    Orange - 28BYJ48 pin 4 --> 33
  Red --> 5V    Black --> GND
*/

// LCD
#include <LiquidCrystal.h>
LiquidCrystal lcd(7, 8, 9, 10, 11 , 12);
// For 2 Arduino Communication
#include <Wire.h>

int k;

int powerLedPin = 13;

int motorPin1 = 30;    // Blue    - 28BYJ48 pin 1
int motorPin2 = 31;    // Pink    - 28BYJ48 pin 2
int motorPin3 = 32;    // Yellow - 28BYJ48 pin 3
int motorPin4 = 33;    // Orange - 28BYJ48 pin 4
```

```

// Red    - 28BYJ48 pin 5 (VCC)
int motorSpeed = 1; //variable to set stepper speed
int count = 0;      // count of steps made
int countsperrev = 512; // number of steps per full revolution
int lookup[8] = {
    B01000, B01100, B00100, B00110, B00010, B00011, B00001, B01001};
// Define colour sensor LED pins
int ledArray[] = {
    2,3,4};
// boolean to know if the balance has been set
boolean whiteBalanceSet = false;
boolean motorTurnABit = false;
boolean blackBalanceSet = false;
//place holders for colour detected
int red = 0;
int green = 0;
int blue = 0;
//floats to hold colour arrays
float colourArray[] = {
    0,0,0};
float whiteArray[] = {
    0,0,0};
float blackArray[] = {
    0,0,0};
//place holder for average
int avgRead;

void setup(){
    Wire.begin(); // join i2c bus (address optional for master)
    lcd.clear();
    Serial.begin(9600);
    lcd.begin(16, 2);
    //begin serial communication
    pinMode(powerLedPin, OUTPUT);
    pinMode(motorPin1, OUTPUT);
    pinMode(motorPin2, OUTPUT);
    pinMode(motorPin3, OUTPUT);
    pinMode(motorPin4, OUTPUT);
    //setup the outputs for the colour sensor
    pinMode(sensorRedPin, OUTPUT);

```

```

pinMode(sensorGreenPin,OUTPUT);
pinMode(sensorBluePin,OUTPUT);
}
//byte x = 0;

void loop(){
  // if I have not finish collecting color yet
  //  if(count<500){
  //  check white balance first
  if (whiteBalanceSet == false){
    checkWhiteBalance();
  }
  // then turn the plate 1/12 to check black balance
  else if(motorTurnABit ==false){
    if(count < 42 ){ // 1/12 circle
      motorSpin();
      count++;
    }
    else {
      motorTurnABit = true;
      Serial.print("whiteBalanceSet= ");
      Serial.println(whiteBalanceSet);
      Serial.print("motorTurnABit= ");
      Serial.println(motorTurnABit);
      Serial.print("blackBalanceSet= ");
      Serial.println(blackBalanceSet);
      Serial.print("Count= ");
      Serial.println(count);
    }
  }
  // then check the black balance
  else if (blackBalanceSet == false ){
    checkBlackBalance();
  }
  // then start sensing colors
  else {
    checkColour();
    delay(10);
  }
  Wire.beginTransmission(4);

```

```

Wire.write("R");
Wire.write(int(colourArray[0]));
Wire.write("G");
Wire.write(int(colourArray[1]));
Wire.write("B");
Wire.write(int(colourArray[2]));
Wire.endTransmission();    // stop transmitting
//x++;
sendDataToProcessing('R',colourArray[0]);
sendDataToProcessing('G',colourArray[1]);
sendDataToProcessing('B',colourArray[2]);
}

void checkWhiteBalance(){
  lcd.setCursor(0,0);
  lcd.write("Balancing White ");
  delay(5000);
  //set white balance
  //delay for five seconds, this gives us time to get a white sample in front of our sensor
  //scan the white sample.
  //go through each light, get a reading, set the base reading for each colour red, green, and blue to the white
  array
  for(int i = 0;i<=2;i++){
    digitalWrite(ledArray[i],HIGH);
    delay(100);
    getReading(5);          //number is the number of scans to take for average, this whole function is
    redundant, one reading works just as well.
    whiteArray[i] = avgRead;
    digitalWrite(ledArray[i],LOW);
    delay(100);
  }
  whiteBalanceSet= true;
  Serial.print("whiteBalanceSet= ");
  Serial.println(whiteBalanceSet);
  Serial.print("motorTurnABit= ");
  Serial.println(motorTurnABit);
  Serial.print("blackBalanceSet= ");
  Serial.println(blackBalanceSet);
  Serial.print("Count= ");
  Serial.println(count);

```

```
}
```

```
void checkBlackBalance(){
    lcd.setCursor(0,0);
    lcd.write("Balancing Black");
    //set black balance
    delay(1000);           //wait for five seconds so we can position our black sample
    //go ahead and scan, sets the colour values for red, green, and blue when exposed to black
    for(int i = 0;i<=2;i++){
        digitalWrite(ledArray[i],HIGH);
        delay(100);
        getReading(5);
        blackArray[i] = avgRead;
        //blackArray[i] = analogRead(2);
        digitalWrite(ledArray[i],LOW);
        delay(100);
    }
    blackBalanceSet = true;
    Serial.print("whiteBalanceSet= ");
    Serial.println(whiteBalanceSet);
    Serial.print("motorTurnABit= ");
    Serial.println(motorTurnABit);
    Serial.print("blackBalanceSet= ");
    Serial.println(blackBalanceSet);
    Serial.print("Count= ");
    Serial.println(count);
    delay(1000);           //delay another 5 seconds to let us catch up
}
```

```
void checkColour(){
    motorSpin();
    count++;
    //lcdShow();
    for(int i = 0;i<=2;i++){
        motorSpin();
        count++;
        digitalWrite(ledArray[i],HIGH); //turn on the LED, red, green or blue depending which iteration
        delay(100);                      //delay to allow CdS to stabilize, they are slow //was 100
        getReading(5);                   //take a reading however many times
        colourArray[i] = avgRead;        //set the current colour in the array to the average reading
    }
```

```

        float greyDiff = whiteArray[i] - blackArray[i];           //the highest possible return minus
the lowest returns the area for values in between
        colourArray[i] = (colourArray[i] - blackArray[i])/(greyDiff)*255; //the reading returned minus the lowest
value divided by the possible range multiplied by 255 will give us a value roughly between 0-255 representing
the value for the current reflectivity(for the colour it is exposed to) of what is being scanned
        digitalWrite(ledArray[i],LOW);    //turn off the current LED
        delay(100);    //was 100
    }
    lcdShow();
}

void getReading(int times){
    int reading;
    int tally=0;
    //take the reading however many times was requested and add them up
    for(int i = 0;i < times;i++){
        reading = analogRead(0);
        tally = reading + tally;
        delay(10);    //was 10
    }
    //calculate the average and set it
    avgRead = (tally)/times;
}

//prints the colour in the colour array, in the next step, we will send this to processing to see how good the sensor
works.
void printColour(){
    Serial.print("R= ");
    Serial.println(int(colourArray[0]));
    Serial.print("G= ");
    Serial.println(int(colourArray[1]));
    Serial.print("B= ");
    Serial.println(int(colourArray[2]));
    //delay(2000);
}

void sendDataToProcessing(char symbol, int data){
    Serial.print(symbol);           // symbol prefix tells Processing what type of data is coming
    Serial.println(data);           // the data to send culminating in a carriage return
}

```

```

void setOutput(int out)
{
    digitalWrite(motorPin1, bitRead(lookup[out], 0));
    digitalWrite(motorPin2, bitRead(lookup[out], 1));
    digitalWrite(motorPin3, bitRead(lookup[out], 2));
    digitalWrite(motorPin4, bitRead(lookup[out], 3));
}

void motorSpin(){
    for(int i = 7; i >= 0; i--){
        {
            setOutput(i);
            delay(motorSpeed);
        }
    }
}

void lcdShow(){
    lcd.clear();
    lcd.setCursor(0,0); // (x=0,y=1)
    lcd.write("Collecting Color");
    lcd.setCursor(0,1); // (x=0,y=1)
    lcd.write("R");
    lcd.setCursor(1,1);
    lcd.print(int(colourArray[0]));
    lcd.setCursor(5,1);
    lcd.write("G");
    lcd.setCursor(6,1);
    lcd.print(int(colourArray[1]));
    lcd.setCursor(10,1);
    lcd.write("B");
    lcd.setCursor(11,1);
    lcd.print(int(colourArray[2]));
}

```

As the original paintings are physical objects, the way *Colour Collector* detects colour information (by analyzing digital images) is somehow problematic. In future work, two practices are suggested. One is to collaborate with research teams of museums or galleries to

work with original paintings (with a new design of colour sensor). Another is to gain more reliable digital formats for analysis.

In addition, there are thousands of colours in a painting. It is thus not possible to read all the colours through the mechanical means I built in *Colour Collector*. The colour wheel is only 12 cm in diameter which cannot hold too many colours as well. In order to solve this problem, I converted the original image into a 256-colour image in *Photoshop* before analyzing them. I realized this quite contradictory when I said I want to analyze the real colour of each painting. Due to this, a means to represent as many colours as possible in a limited surface will need to be further explored in future work of *Experiential Converter*. A *Colour Collector* with a more flexible mechanism of reading colours (possibly in a spiral movement) will also be a future challenge.

For the *Motion Converter*, I used three servo motors, rgb leds, and an *Arduino Mega* board and developed the following *Arduino* code that can convert colour into dynamic motion (see main text for more detail):

```
// Servo motors
// Orange to 7, Red to 5V, Brown to GND
#include <Servo.h>
Servo myBServo;
Servo myMServo;
Servo mySServo;
// RGB led 1(up)
// 1st:R, 2nd:GND, 3rd:G, 4th:B
int red1Pin = 2; // connect with 1st
int green1Pin = 3; // connect with 3rd
int blue1Pin = 4; // connect with 4th
// RGB led 2(Middle)
// 1st:R, 2nd:GND, 3rd:G, 4th:B
int red2Pin = 11; // connect with 1st
int green2Pin = 12; // connect with 3rd
```

```

int blue2Pin = 13; // connect with 4th
// RGB led 3(down)
// 1st:R, 2nd:GND, 3rd:G, 4th:B
int red3Pin = 8; // connect with 1st
int green3Pin = 9; // connect with 3rd
int blue3Pin = 10; // connect with 4th
int R;
int G;
int B;
int rPos;
int gPos;
int bPos;
#include <Wire.h>
int x1;
int x2;
int x3;

void setup(){
  myBServo.attach(7);
  myMServo.attach(6);
  mySServo.attach(5);
  //declare the motor pins as outputs
  pinMode(red1Pin, OUTPUT);
  pinMode(green1Pin, OUTPUT);
  pinMode(blue1Pin, OUTPUT);
  pinMode(red2Pin, OUTPUT);
  pinMode(green2Pin, OUTPUT);
  pinMode(blue2Pin, OUTPUT);
  pinMode(red3Pin, OUTPUT);
  pinMode(green3Pin, OUTPUT);
  pinMode(blue3Pin, OUTPUT);
  Serial.begin(9600);
  Wire.begin(4); // join i2c bus with address #4
  Wire.onReceive(receiveEvent); // register event
}

void loop(){
  // R= random(255); // this is for filming video
  // G= random(255);
  //B= random(255);

```

```

R= int(x1);
G= int(x2);
B= int(x3);
rPos = map(R,0,255,30,150); // 30-150
gPos = map(G,0,255,10,140); // 0-120
bPos = map(B,0,255,30,150);
setColor(R,G,B);
myBServo.write(rPos);
myMServo.write(gPos);
mySServo.write(bPos);
Serial.print("R");
Serial.println(rPos);
Serial.print("G");
Serial.println(gPos);
Serial.print("B");
Serial.println(bPos);
delay(800); // for real data, delay(10)
}
////////////////////////////////////
//set pins to ULN2003 high in sequence from 1 to 4
//delay "motorSpeed" between each pin setting (to determine speed)
void setColor(int red, int green, int blue)
{
  analogWrite(red1Pin, red);
  analogWrite(green1Pin, green);
  analogWrite(blue1Pin, blue);
  analogWrite(red2Pin, red);
  analogWrite(green2Pin, green);
  analogWrite(blue2Pin, blue);
  analogWrite(red3Pin, red);
  analogWrite(green3Pin, green);
  analogWrite(blue3Pin, blue);
}

void receiveEvent(int howMany)
{
  while(1 < Wire.available()) // loop through all but the last,
  {
    //Wire.parseInt();
    char c1 = Wire.read(); // receive byte as a character

```

```

//Serial.print(c1);
x1 = Wire.read();    // receive byte as an integer
// Serial.println(x1);    // print the integer
char c2 = Wire.read();
//Serial.print(c2);
x2 = Wire.read();    // receive byte as an integer
//Serial.println(x2);    // print the integer
char c3 = Wire.read();
//Serial.print(c3);
x3 = Wire.read();    // receive byte as an integer
// Serial.println(x3);    // print the integer
}
}

```

As the above code shows, I mapped the R, G and B values into angles for the servomotors to perform. In order to make it fully functional, two big servomotors and one small servomotor were used. The servomotors did a proper job to move the RGB lantern into a specific position. However, in order to keep up the speed of *Colour Collector*, the servomotors sometimes receive a new command before arriving the current position. This caused some problems for the mechanism. Based on the experience throughout this project, I suggest use stepper motors and design a mechanism with less friction for future project. I also suggest slow down the whole technical process of colour-sound conversion, as it may reduce mechanical problems.

14. TimeFlower

In the making of *TimeFlower*, I firstly intended to show the visualisation with the actual time reading. However, a few discussions with colleagues and some feedback from seminars suggested that the actual time reading made the work less wondrous. Feedback suggested that the time reading stop the viewers from exploring the details and thinking about what was happening in the dynamic image. This feedback suggested that I should intentionally hide from the audience the information that dominated *TimeFlower* or diminish the actual mechanism that functioned. Therefore, later developments of *TimeFlower* explored how an

information-oriented visualisation may be displayed to engender wonder and discussion with a magic-like setting. The final *Processing* code of *TimeFlower* is:

```
// Time Flower    Ping-Yeh Li 2013    Processing 2.0b9
import processing.sound.*;
SoundFile file;
import oscP5.*;
import netP5.*;
NetAddress myOwnPdLocation;
Boolean oscSent= false;
Boolean addingRandom= false;
Boolean playSound = false;
PShape leaves01;
PShape leaves02;
PShape leaves03;
PShape leaves04;
PShape leaves05;
PShape leaves06;
PShape heart01;
PShape heart03;
PShape gear01;
float angle1;
float angle2;
float angle3;
float angle4;
float angle5;
boolean blurSwitch= true;
PFont font;
boolean oneSecPassed = false;
int previousValue= -1;
int frameRateSet=30;
int numOfPoints = 1000;
float[] xPositions= new float[numOfPoints];
float[] yPositions= new float[numOfPoints];
float[] zPositions= new float[numOfPoints];
String[] data= {
    "0", "0", "0", "0", "0"
};
```

```

int passedTime;
int currentTime;
PImage cover;
OscP5 oscP5;
OSCsender oscsender;
float v = 1.0 / 9;
float[][] kernel = {
    {
        v, v, v
    },
    {
        v, v, v
    },
    {
        v, v, v
    }
};
Points[] myPoints;

void setup() {
    file = new SoundFile(this, "tick.mp3");
    oscP5 = new OscP5(this, 7000);
    oscsender = new OSCsender();
    font= loadFont("Serif-20.vlw");
    frameRate(frameRateSet);
    background(0);
    size(500, 600, P3D);
    colorMode(HSB, 255);
    shapeMode(CENTER);
    imageMode(CENTER);
    smooth();
    myPoints = new Points[numOfPoints];
    for (int i=0; i<numOfPoints; i++) {
        xPositions[i] = random(-width/2, width/2);
        yPositions[i] = random(-height/2, height/2);
        zPositions[i] = random(5);
        myPoints[i] = new Points(i, xPositions[i], yPositions[i], zPositions[i]);
    }
}

```

```

// The file "bot.svg" must be in the data folder
// of the current sketch to load successfully
leaves01 = loadShape("leaves01.svg");
leaves02 = loadShape("leaves02.svg");
leaves03 = loadShape("leaves03.svg");
leaves04= loadShape("leaves04.svg");
leaves05= loadShape("leaves05.svg");
leaves06= loadShape("leaves06.svg");
heart01= loadShape("heart01.svg");
heart03= loadShape("heart03.svg");
gear01= loadShape("gear01.svg");
cover= loadImage("cover.png");
myOwnPdLocation =new NetAddress("127.0.0.1", 9001);
}

void draw() {
  // display all the points here
  pushMatrix();
  translate(width/2, height/2, 20);
  rotate(-angle2*1.5);
  for (int i=0; i<numOfPoints; i++) {
    myPoints[i].display(i);
  }
  popMatrix();
  currentTime = millis();
  if (blurSwitch==false) {
    background(0);
  }
  int secs = second();
  int mins = minute();
  int h = hour();
  if (millis()%2000 < 50) {
    file.play();
  } else if (millis()%2000 > 50) {
    file.stop();
  }
  if (oneSecPassed==true) {
    angle1+=0.002;
    angle2+=0.003;

```

```

    angle3+=0.004;
    angle4+=0.005;
    for (int i=0; i<numOfPoints; i++) {
        myPoints[i].addRandom(i);
    }
    oscSent= true;
} else {
    angle1+=0.0002;
    angle2+=0.0003;
    angle3+=0.0004;
    angle4+=0.0005;
    oscSent= false;
}
angle5+=0.0005;
// draw 8th layer (gear)
pushMatrix();
translate(width/2, height/2, 3);
rotate(-angle2);
shape(gear01, 0, 0, 50, 50);
popMatrix();
// draw 5th layer (leaves)
pushMatrix();
translate(width/2, height/2, 6);
rotate(-angle1*3);
shape(leaves05, 0, 0, 120+cos(angle4)*60, 120+cos(angle4)*60);
popMatrix();
// draw 4th layer (leaves)
pushMatrix();
translate(width/2, height/2, 7);
rotate(angle2);
leaves04.disableStyle();
fill(map(secs, 0, 60, 0, 255), map(mins, 0, 60, 0, 255), map(h, 0, 24, 0, 255));
shape(leaves04, 0, 0, 100+sin(angle1*6)*30, 100+sin(angle1*6)*30);
popMatrix();

// draw 2nd layer (leaves)
pushMatrix();
translate(width/2, height/2, 9);
rotate(angle3);
leaves02.disableStyle();

```



```

fill(map(secs, 0, 60, 0, 255), map(h, 0, 24, 0, 255), map(mins, 0, 60, 0, 255));
shape(leaves02, 0, 0, 205, 205);
popMatrix();

// draw 1st layer (leaves)
pushMatrix();
translate(width/2, height/2, 10);
rotate(angle5*2);
leaves01.disableStyle();
fill(map(h, 0, 24, 0, 255), map(secs, 0, 60, 0, 255), map(mins, 0, 60, 0, 255));
//shape(leaves01, 0, 0, 150+sin(angle2*5)*120, 150+sin(angle2*5)*120); // small flower
shape(leaves01, 0, 0, 150+sin(angle2*5)*900, 150+sin(angle2*5)*900); // huge flower
popMatrix();

// draw top layer (heart03)
pushMatrix();
translate(width/2, height/2, 20);
rotate(-angle4);
shape(heart03, 0, 0, 100+sin(angle4*5)*30, 100+sin(angle4*5)*30);
popMatrix();

// draw 8th layer (heart)
pushMatrix();
translate(width/2, height/2, 120+sin(angle5*100)*100);
//rotate(-angle4*3);
shape(heart01, 0, 0, 20, 20);
popMatrix();
pushMatrix();
translate(width/2, height/2, 200);
image(cover, 0, 0, width/(1.4+sin(angle2*5)*0.2), height/(1.4+sin(angle2*5)*0.2));
height/(1.3+sin(angle2*10)*0.1)); // for size 600*750
popMatrix();

if (blurSwitch==true) {
  loadPixels();
  // Create an opaque image of the same size as the original
  // Loop through every pixel in the image
  for (int y = 1; y < height-1; y+=1) { // Skip top and bottom edges
    for (int x = 1; x < width-1; x+=1) { // Skip left and right edges
      float sum1 = 0; // Kernel sum for this pixel

```

```

float sum2 = 0;
float sum3 = 0;
for (int ky = -1; ky <= 1; ky++) {
    for (int kx = -1; kx <= 1; kx++) {
        // Calculate the adjacent pixel for this kernel point
        int pos = (y + ky)*width + (x + kx);
        // Image's red/green/blue are identical   hue/saturation/brightness
        float valH = hue(pixels[pos]);
        float valS= saturation(pixels[pos]);
        float valB= brightness(pixels[pos]);
        // Multiply adjacent pixels based on the kernel values
        sum1 += kernel[ky+1][kx+1] * valH;
        sum2 += kernel[ky+1][kx+1] * valS;
        sum3 += kernel[ky+1][kx+1] * valB;
    }
}
// For this pixel in the new image, set the gray value
// based on the sum from the kernel
pixels[y*width + x] = color(sum1, sum2, sum3);
}
}
// State that there are changes to edgeImg.pixels[]
updatePixels();
}

int currentSecs=(h*60*60)+(mins*60)+(secs);
String currentSecsString= String.valueOf(currentSecs);
//text(currentSecsString, width*0.2+230, height*0.95);
if (currentSecs<10) {
    data[4]= currentSecsString.substring(0, 1);
}
if (currentSecs>9 && currentSecs<100) {
    data[4]= currentSecsString.substring(1, 2);
}
if (currentSecs>99 && currentSecs<1000) {
    data[4]= currentSecsString.substring(2, 3);
}
if (currentSecs>999 && currentSecs<10000) {
    data[4]= currentSecsString.substring(3, 4);
} else {

```

```

    data[4]= currentSecsString.substring(4, 5);
}
//int value01= Integer.parseInt(data[0]); //
// int value02= Integer.parseInt(data[1]); //
//int value03= Integer.parseInt(data[2]); //
//int value04= Integer.parseInt(data[3]); //
int value05= Integer.parseInt(data[4]); //
if (value05==0 || value05==2 || value05==4 || value05==6 || value05==8) {
    if (previousValue!=value05) {
        oneSecPassed= true;
        previousValue= value05;
    }
} else {
    oneSecPassed= false;
};
fill(255);
textFont(font, 24);

if (mousePressed) {
    save("imageCapture/011.png");
    exit();
}
if (oscSent== true) {
    oscsender.sendOSCtoPd(1, int(xPositions[0]), int(yPositions[0]), int(xPositions[numOfPoints/5]),
int(yPositions[numOfPoints/5]), int(xPositions[numOfPoints/2]), int(yPositions[numOfPoints/2]),
int(xPositions[numOfPoints-1]), int(yPositions[numOfPoints-1]));
} else {
    oscsender.sendOSCtoPd(0, 0, 0, 0, 0, 0, 0, 0, 0);
}
}

void playSound() {
    file.play();
    playSound = false;
}

```

As the above code shows, the visual design of *TimeFlower* was a process of various experimentations on the visual effects through coding in *Processing*. I created different shapes in *Adobe Illustrator* (leaves, hearts and gear), loaded them and controlled their behaviours on

the screen. The ‘blur function’ (as I indicate as ‘blurSwitch’ in the code) could create some random effects while different layers were combined and interwoven. This allowed rich possibilities in visual design. For example, by changing the angles for rotation of the leaves (float’ angle01’ - ‘angle04’) or the sizes of the shapes (values in the ‘shape()’ function), the visualisation of *TimeFlower* could become very different. It was also interesting to switch the colour mode between RGB and HSB to see the different colour combinations. Sometimes I went back to shape design in *Illustrator* to explore whether a change of shapes could lead to better visualisation. The making of *TimeFlower* is thus a reciprocal process of experiment and evaluation. This suggests that the development of visual design through *Processing* can be a nonlinear progress. It can be rather playful and experimental.

15. Botanical Universe

The making of *Botanical Universe* allowed me to learn about how laser cut materials and electronic components could be assembled into a three dimensional sculpture. I used white glue instead of screws to reduce the work’s weight, which also helped reduce the friction in mechanism. Much experimentation was conducted in assembling the MDFs in different ways. Adobe *Illustrator* was helpful in this process. I started with cutting a few 3mm MDFs to play with before using 6mm MDFs for the final artwork. *Illustrator* was convenient for scaling such complex design. The smaller scale of 3mm MDFs was also handier for experimenting different formations and shapes for the final piece.



The making of *Botanical Universe* started with the construction of a pair of functional mechanical arms (see image above). The main challenge was to create less friction (by sanding the MDFs and acrylic, or giving a gap between two frictional surfaces) while fully extending and shrinking the mechanical arms. After finishing one functional mechanism, it was then duplicated and juxtaposed to construct a more complex structure. I used *Adafruit 16 channel board* and developed *Arduino* software for testing the mechanical arms:

```
#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>
// called this way, it uses the default address 0x40
Adafruit_PWMServoDriver pwm = Adafruit_PWMServoDriver();
#define SERVOMIN 150 // this is the 'minimum' pulse length count (out of 4096) was 150 (adjusted for my
push arm)
#define SERVOMAX 450 // this is the 'maximum' pulse length count (out of 4096) was 600 (adjusted for my
push arm)
// our servo # counter
uint8_t servonum = 0;

void setup() {
  Serial.begin(9600);
  Serial.println("16 channel Servo test!");
  pwm.begin();
  pwm.setPWMFreq(50); // Analog servos run at ~60 Hz updates// MG90S== 50Hz
}
```

```

// you can use this function if you'd like to set the pulse length in seconds
// e.g. setServoPulse(0, 0.001) is a ~1 millisecond pulse width. its not precise!
void setServoPulse(uint8_t n, double pulse) {
    double pulselength;
    pulselength = 1000000;    // 1,000,000 us per second
    pulselength /= 50;        // 50 Hz for MG90S
    Serial.print(pulselength);
    Serial.println(" us per period");
    pulselength /= 4096;      // 12 bits of resolution
    Serial.print(pulselength);
    Serial.println(" us per bit");
    pulse *= 1000;
    pulse /= pulselength;
    Serial.println(pulse);
    pwm.setPWM(n, 0, pulse);
}

void loop() {
    // Drive each servo one at a time
    Serial.println(servonum);
    for (uint16_t pulselen = SERVOMIN; pulselen < SERVOMAX; pulselen++) {
        pwm.setPWM(0, 0, pulselen);
        // pwm.setPWM(1, 0, pulselen);
        // pwm.setPWM(2, 0, pulselen);
        // pwm.setPWM(3, 0, pulselen);
        // pwm.setPWM(4, 0, pulselen);
        // pwm.setPWM(5, 0, pulselen);
        // pwm.setPWM(6, 0, pulselen);
        // pwm.setPWM(7, 0, pulselen);
        pwm.setPWM(8, 0, pulselen);
        pwm.setPWM(9, 0, pulselen);
        delay(35);
    }
    delay(2000);
    for (uint16_t pulselen = SERVOMAX; pulselen > SERVOMIN; pulselen--) {
        pwm.setPWM(0, 0, pulselen);
        // pwm.setPWM(1, 0, pulselen);
        // pwm.setPWM(2, 0, pulselen);
        // pwm.setPWM(3, 0, pulselen);
        // pwm.setPWM(4, 0, pulselen);

```

```

    // pwm.setPWM(5, 0, pulselen);
    // pwm.setPWM(6, 0, pulselen);
    //pwm.setPWM(7, 0, pulselen);
    pwm.setPWM(8, 0, pulselen);
    pwm.setPWM(9, 0, pulselen);
    delay(35);
  }
  delay(8000);
}

```

In the making of *Botanical Clock*, I used soil moisture sensor, light sensor, air humidity sensor and temperature sensor to detect the environmental condition. The readings were compared and converted into ‘modes’ for the mechanism to perform. The *Arduino* code for detecting the environmental condition and move the mechanical arms is:

```

/*
  This code is for Exhibition in Space 4 Culture Lab
  The sensors detects the environment, decide mode 0-1-2-3
  and show light and soil humidity on the center clock
  and shows the motions
  DHT11 data to Arduino digital 4
  Photoresistor data to Arduino Analog 1, 2 and 3 (each using 10ku resistor)
  FC-28 A0 to Arduino A0
  And let them share the same 5V and GND
  I use Ivy in the exhibition
*/

#include <DHT11.h>
int DHTpin=4; // connect DHT11 data to Arduino digital 4
int PhotoR1=1; // connect photoresistor1 data to Arduino A1
int PhotoR2=2; // connect photoresistor2 data to Arduino A2
int PhotoR3=3; // connect photoresistor3 data to Arduino A3
int ledPin00= 13;
int ledPin01= 12;
int ledPin02= 11;
int ledPin03= 10;
DHT11 dht11(DHTpin);

```

```

int plantTemp= 21; // SET: what temperature is perfect for this plant? Ivy day 20-22 night 10-12.7
int plantMoisture= 70; // SET: what Soil Moisture % is perfect for this plant?
int plantLight= 70; // SET: What light is perfect for this plant?
int plantHumi = 50; // SET: What air humidity is perfect for this plant?
int checkGap = 10000; // SET: set checkGap time here (in mini-second)
int mode;
unsigned long time;
unsigned long savedTime;
boolean checkMode = false;

#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>
// called this way, it uses the default address 0x40
Adafruit_PWMServoDriver pwm = Adafruit_PWMServoDriver();
// you can also call it with a different address you want
//Adafruit_PWMServoDriver pwm = Adafruit_PWMServoDriver(0x41);

// Depending on your servo make, the pulse width min and max may vary, you
// want these to be as small/large as possible without hitting the hard stop
// for max range. You'll have to tweak them as necessary to match the servos you
// have!
#define SERVOMIN 140 // this is the 'minimum' pulse length count (out of 4096) was 150 (adjusted for my
push arm)
#define SERVOMAX 450 // this is the 'maximum' pulse length count (out of 4096) was 600 (adjusted for my
push arm)
boolean motorReset = false;
// our servo # counter
uint8_t servonum = 0;
int lightAverage;
int soilMoisture;

void setup()
{
  pinMode(ledPin00, OUTPUT);
  pinMode(ledPin01, OUTPUT);
  pinMode(ledPin02, OUTPUT);
  pinMode(ledPin03, OUTPUT);
  Serial.begin(9600);
  pwm.begin();
  pwm.setPWMFreq(50); // Analog servos run at ~60 Hz updates// MG90S== 50Hz

```



```

/*
while (!Serial) {
    ; // wait for serial port to connect. Needed for Leonardo only
}
*/
}

// you can use this function if you'd like to set the pulse length in seconds
// e.g. setServoPulse(0, 0.001) is a ~1 millisecond pulse width. its not precise!
void setServoPulse(uint8_t n, double pulse) {
    double pulselength;
    pulselength = 1000000;    // 1,000,000 us per second
    pulselength /= 50;        // 50 Hz for MG90S
    Serial.print(pulselength);
    Serial.println(" us per period");
    pulselength /= 4096;      // 12 bits of resolution
    Serial.print(pulselength);
    Serial.println(" us per bit");
    pulse *= 1000;
    pulse /= pulselength;
    Serial.println(pulse);
    pwm.setPWM(n, 0, pulse);
}

void loop()
{
    reCheck();
    Serial.print("Mode= ");
    Serial.println(mode); // 0 1 2 3 4
    delay(4000);
    // show soilMoisture in the Center-Clock
    int moisPos=map(soilMoisture,0,100,SERVOMIN,SERVOMAX);
    Serial.print("moisPos= ");
    Serial.println(moisPos);
    pwm.setPWM(8,0,moisPos);
    delay(4000);
    // show lightAverage in the Center-Clock
    int lightPos=map(lightAverage,0,100,SERVOMIN,SERVOMAX);
    Serial.print("lightPos= ");
    Serial.println(lightPos);
    pwm.setPWM(9,0,lightPos);
}

```

```

delay(4000);

if (mode==0){
    // reset first
    Serial.println("reseting for motion 0");
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN);
    delay(500);
    pwm.setPWM(1,0,SERVOMIN);
    delay(500);
    pwm.setPWM(2,0,SERVOMIN);
    delay(500);
    pwm.setPWM(3,0,SERVOMIN);
    delay(500);
    pwm.setPWM(4,0,SERVOMIN);
    delay(500);
    pwm.setPWM(5,0,SERVOMIN);
    delay(500);
    pwm.setPWM(6,0,SERVOMIN);
    delay(500);
    pwm.setPWM(7,0,SERVOMIN);
    delay(500);
    // do the motion 0 - RHYTHM UP AND RHYTHM DOWN
    Serial.println("doing motion 0");
    mode00Up();
    mode00Down();
    mode00Up();
    mode00Down();
    mode00Up();
    mode00Down();
    mode00Up();
    mode00Down();
}

if (mode==1){
    // reset first
    Serial.println("reseting for motion 1");
    digitalWrite(ledPin01, HIGH);
    pwm.setPWM(0,0,SERVOMIN);
    delay(500);

```

```

    pwm.setPWM(1,0,SERVOMIN);
    delay(500);
    pwm.setPWM(2,0,SERVOMIN);
    delay(500);
    pwm.setPWM(3,0,SERVOMIN);
    delay(500);
    pwm.setPWM(4,0,SERVOMIN);
    delay(500);
    pwm.setPWM(5,0,SERVOMIN);
    delay(500);
    pwm.setPWM(6,0,SERVOMIN);
    delay(500);
    pwm.setPWM(7,0,SERVOMIN);
    delay(500);
    int count_=0;
    while (count_<360){
        count_++;
        int pos=map(count_,0,360,SERVOMIN,SERVOMAX);
        pwm.setPWM(1,0,pos);
        pwm.setPWM(3,0,pos);
        pwm.setPWM(5,0,pos);
        pwm.setPWM(7,0,pos);
        delay(20);
    }
    // do the motion 1 - 0246OUT when 1357IN - 0246IN when 1357OUT - AND ALL RETURN TO
CENTER AT LAST
    Serial.println("doing motion 1");
    mode01(); // mode01() will finally goes back to center
}

if (mode==2){
    // reset first
    Serial.println("reseting for motion 2");
    digitalWrite(ledPin02, HIGH);
    pwm.setPWM(0,0,SERVOMIN);
    delay(500);
    pwm.setPWM(1,0,SERVOMIN);
    delay(500);
    pwm.setPWM(2,0,SERVOMIN);
    delay(500);

```

```

    pwm.setPWM(3,0,SERVOMIN);
    delay(500);
    pwm.setPWM(4,0,SERVOMIN);
    delay(500);
    pwm.setPWM(5,0,SERVOMIN);
    delay(500);
    pwm.setPWM(6,0,SERVOMIN);
    delay(500);
    pwm.setPWM(7,0,SERVOMIN);
    delay(500);
    // do the motion 2 - 0246OUT - 1357OUT - 0246IN - 1357IN
    Serial.println("doing motion 2");
    mode02();
    mode02();
    mode02();
}
if (mode==3){

    // reset first
    Serial.println("reseting for motion 3");
    digitalWrite(ledPin03, HIGH);
    pwm.setPWM(0,0,SERVOMIN);
    delay(500);
    pwm.setPWM(1,0,SERVOMIN);
    delay(500);
    pwm.setPWM(2,0,SERVOMIN);
    delay(500);
    pwm.setPWM(3,0,SERVOMIN);
    delay(500);
    pwm.setPWM(4,0,SERVOMIN);
    delay(500);
    pwm.setPWM(5,0,SERVOMIN);
    delay(500);
    pwm.setPWM(6,0,SERVOMIN);
    delay(500);
    pwm.setPWM(7,0,SERVOMIN);
    delay(500);
    // do the motion 3 - SLOW ALL OUT - FAST ALL IN
    Serial.println("doing motion 3");
    mode03();

```

```

        mode03();
        mode03();
    }
}

void reCheck(){
    digitalWrite(ledPin00, LOW);
    digitalWrite(ledPin01, LOW);
    digitalWrite(ledPin02, LOW);
    digitalWrite(ledPin03, LOW);
    // Re-checking the environment and get a new mode
    Serial.println("Re-Checking Environment !!");
    int lightQuantity1 = map(analogRead(PhotoR1),1023,0,0,100);
    //Serial.print("LightQuantity1:");
    //Serial.print(lightQuantity1);    // weak 0% --> strong 100%
    //Serial.println("%");
    // delay(100);
    int lightQuantity2 = map(analogRead(PhotoR2),1023,0,0,100);
    //Serial.print("LightQuantity2:");
    //Serial.print(lightQuantity2);    // weak 0% --> strong 100%
    //Serial.println("%");
    //delay(100);
    int lightQuantity3 = map(analogRead(PhotoR3),1023,0,0,100);
    // Serial.print("LightQuantity3:");
    //Serial.print(lightQuantity3);    // weak 0% --> strong 100%
    //Serial.println("%");
    //delay(100);
    lightAverage = (lightQuantity1+ lightQuantity2 + lightQuantity3)/3;
    Serial.print("  Light Average:");
    Serial.print(lightAverage);    // weak 0% --> strong 100%
    Serial.println("%");
    soilMoisture = map(analogRead(A0),1023,0,0,100);
    Serial.print("  SoilMoisture:");
    Serial.print(soilMoisture);    // // dry 0% --> wet 100%
    Serial.println("%");
    int err;
    float temp, humi;
    if((err=dht11.read(humi, temp))==0)
    {
        Serial.print("  Temperature:");

```

```

    Serial.println(temp);
    Serial.print("  AirHumidity:");
    Serial.println(humi);
    //Serial.println();
}
else
{
    Serial.println();
    Serial.print("Error No :");
    Serial.print(err);
    Serial.println();
}
float tempDistance= abs(temp-plantTemp);
Serial.print("tempDistance:");
Serial.println(tempDistance);
float humiDistance = abs(humi-plantHumi);
Serial.print("humiDistance:");
Serial.println(humiDistance);
float moisDistance = abs(soilMoisture-plantMoisture);
Serial.print("moisDistance:");
Serial.println(moisDistance);
float lightDistance = abs(lightAverage-plantLight);
Serial.print("lightDistance:");
Serial.println(lightDistance);
int totalDistance= tempDistance*4+moisDistance+humiDistance+lightDistance;
Serial.print("totalDistance:");
Serial.println(totalDistance);
if (totalDistance<70){
    mode=0;
}
else if (totalDistance>=70 && totalDistance< 100){
    mode=1;
}
else if (totalDistance>=100 && totalDistance< 150){
    mode=2;
}
else{ //( totalDistance>=150)
    mode=3;
}
delay(DHT11_RETRY_DELAY); //delay for reread

```

```
}
```

```
void mode00Up(){
  // SERVOMIN =140, SERVOMAX=450
  // rhytem move
  // total is (450-140)*2= 620 counts
  // 620/16(because we have 8 motors)=38.7 per step
  uint16_t pulselen = SERVOMIN;
  while(pulselen < 140+620){
    digitalWrite(ledPin00, HIGH);
    pulselen++;
    if(pulselen>=SERVOMIN && pulselen <SERVOMIN+38.7){
      digitalWrite(ledPin00, HIGH);
      pwm.setPWM(0,0,pulselen);
      delay(35);
    }
    if(pulselen>=SERVOMIN+38.7 && pulselen <SERVOMIN +(38.7*2)){
      digitalWrite(ledPin00, HIGH);
      pwm.setPWM(0,0,pulselen);
      pwm.setPWM(1,0,pulselen-38.7);
      delay(35);
    }
    if(pulselen>=SERVOMIN+(38.7*2) && pulselen <SERVOMIN+(38.7*3)){
      digitalWrite(ledPin00, HIGH);
      pwm.setPWM(0,0,pulselen);
      pwm.setPWM(1,0,pulselen-38.7);
      pwm.setPWM(2,0,pulselen-(38.7*2));
      delay(35);
    }
    if(pulselen>=SERVOMIN+(38.7*3) && pulselen <SERVOMIN +(38.7*4)){
      digitalWrite(ledPin00, HIGH);
      pwm.setPWM(0,0,pulselen);
      pwm.setPWM(1,0,pulselen-38.7);
      pwm.setPWM(2,0,pulselen-(38.7*2));
      pwm.setPWM(3,0,pulselen-(38.7*3));
      delay(35);
    }
    if(pulselen>=SERVOMIN+(38.7*4) && pulselen <SERVOMIN +(38.7*5)){
      digitalWrite(ledPin00, HIGH);
      pwm.setPWM(0,0,pulselen);
```

```

    pwm.setPWM(1,0,pulselen-38.7);
    pwm.setPWM(2,0,pulselen-(38.7*2));
    pwm.setPWM(3,0,pulselen-(38.7*3));
    pwm.setPWM(4,0,pulselen-(38.7*4));
    delay(35);
}

if(pulselen>=SERVOMIN+(38.7*5) && pulselen <SERVOMIN +(38.7*6)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,pulselen);
    pwm.setPWM(1,0,pulselen-38.7);
    pwm.setPWM(2,0,pulselen-(38.7*2));
    pwm.setPWM(3,0,pulselen-(38.7*3));
    pwm.setPWM(4,0,pulselen-(38.7*4));
    pwm.setPWM(5,0,pulselen-(38.7*5));
    delay(35);
}

if(pulselen>=SERVOMIN+(38.7*6) && pulselen <SERVOMIN +(38.7*7)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,pulselen);
    pwm.setPWM(1,0,pulselen-38.7);
    pwm.setPWM(2,0,pulselen-(38.7*2));
    pwm.setPWM(3,0,pulselen-(38.7*3));
    pwm.setPWM(4,0,pulselen-(38.7*4));
    pwm.setPWM(5,0,pulselen-(38.7*5));
    pwm.setPWM(6,0,pulselen-(38.7*6));
    delay(35);
}

if(pulselen>=SERVOMIN+(38.7*7) && pulselen <SERVOMIN +(38.7*8)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,pulselen); // this one will be approaching 449.6
    pwm.setPWM(1,0,pulselen-38.7);
    pwm.setPWM(2,0,pulselen-(38.7*2));
    pwm.setPWM(3,0,pulselen-(38.7*3));
    pwm.setPWM(4,0,pulselen-(38.7*4));
    pwm.setPWM(5,0,pulselen-(38.7*5));
    pwm.setPWM(6,0,pulselen-(38.7*6));
    pwm.setPWM(7,0,pulselen-(38.7*7));
    delay(35);
}

if(pulselen>=SERVOMIN+(38.7*8) && pulselen <SERVOMIN +(38.7*9)){

```



```

digitalWrite(ledPin00, HIGH);
pwm.setPWM(0,0,SERVOMAX); // stay at SERVOMAX = 450
pwm.setPWM(1,0,pulselen-38.7);
pwm.setPWM(2,0,pulselen-(38.7*2));
pwm.setPWM(3,0,pulselen-(38.7*3));
pwm.setPWM(4,0,pulselen-(38.7*4));
pwm.setPWM(5,0,pulselen-(38.7*5));
pwm.setPWM(6,0,pulselen-(38.7*6));
pwm.setPWM(7,0,pulselen-(38.7*7));
delay(35);
}
if(pulselen>=SERVOMIN+(38.7*9) && pulselen <SERVOMIN +(38.7*10)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMAX);
    pwm.setPWM(1,0,SERVOMAX);
    pwm.setPWM(2,0,pulselen-(38.7*2));
    pwm.setPWM(3,0,pulselen-(38.7*3));
    pwm.setPWM(4,0,pulselen-(38.7*4));
    pwm.setPWM(5,0,pulselen-(38.7*5));
    pwm.setPWM(6,0,pulselen-(38.7*6));
    pwm.setPWM(7,0,pulselen-(38.7*7));
    delay(35);
}
if(pulselen>=SERVOMIN+(38.7*10) && pulselen <SERVOMIN+(38.7*11)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMAX);
    pwm.setPWM(1,0,SERVOMAX);
    pwm.setPWM(2,0,SERVOMAX);
    pwm.setPWM(3,0,pulselen-(38.7*3));
    pwm.setPWM(4,0,pulselen-(38.7*4));
    pwm.setPWM(5,0,pulselen-(38.7*5));
    pwm.setPWM(6,0,pulselen-(38.7*6));
    pwm.setPWM(7,0,pulselen-(38.7*7));
    delay(35);
}
if(pulselen>=SERVOMIN+(38.7*11) && pulselen <SERVOMIN +(38.7*12)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMAX);
    pwm.setPWM(1,0,SERVOMAX);
    pwm.setPWM(2,0,SERVOMAX);

```

```

    pwm.setPWM(3,0,SERVOMAX);
    pwm.setPWM(4,0,pulselen-(38.7*4));
    pwm.setPWM(5,0,pulselen-(38.7*5));
    pwm.setPWM(6,0,pulselen-(38.7*6));
    pwm.setPWM(7,0,pulselen-(38.7*7));
    delay(35);
}

if(pulselen>=SERVOMIN+(38.7*12) && pulselen <SERVOMIN +(38.7*13)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMAX);
    pwm.setPWM(1,0,SERVOMAX);
    pwm.setPWM(2,0,SERVOMAX);
    pwm.setPWM(3,0,SERVOMAX);
    pwm.setPWM(4,0,SERVOMAX);
    pwm.setPWM(5,0,pulselen-(38.7*5));
    pwm.setPWM(6,0,pulselen-(38.7*6));
    pwm.setPWM(7,0,pulselen-(38.7*7));
    delay(35);
}

if(pulselen>=SERVOMIN+(38.7*13) && pulselen <SERVOMIN +(38.7*14)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMAX);
    pwm.setPWM(1,0,SERVOMAX);
    pwm.setPWM(2,0,SERVOMAX);
    pwm.setPWM(3,0,SERVOMAX);
    pwm.setPWM(4,0,SERVOMAX);
    pwm.setPWM(5,0,SERVOMAX);
    pwm.setPWM(6,0,pulselen-(38.7*6));
    pwm.setPWM(7,0,pulselen-(38.7*7));
    delay(35);
}

if(pulselen>=SERVOMIN+(38.7*14) && pulselen <SERVOMIN +(38.7*15)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMAX);
    pwm.setPWM(1,0,SERVOMAX);
    pwm.setPWM(2,0,SERVOMAX);
    pwm.setPWM(3,0,SERVOMAX);
    pwm.setPWM(4,0,SERVOMAX);
    pwm.setPWM(5,0,SERVOMAX);
    pwm.setPWM(6,0,SERVOMAX);

```

```

    pwm.setPWM(7,0,pulselen-(38.7*7));
    delay(35);
}
if(pulselen>=SERVOMIN+(38.7*15) && pulselen <SERVOMIN +(38.7*16)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMAX);
    pwm.setPWM(1,0,SERVOMAX);
    pwm.setPWM(2,0,SERVOMAX);
    pwm.setPWM(3,0,SERVOMAX);
    pwm.setPWM(4,0,SERVOMAX);
    pwm.setPWM(5,0,SERVOMAX);
    pwm.setPWM(6,0,SERVOMAX);
    pwm.setPWM(7,0,SERVOMAX);
    delay(35);
}
}
}

```

```

void mode00Down(){
    uint16_t pulselen = 140+620;  // from the top (140+620) to count down to 140

    while(pulselen>SERVOMIN){
        digitalWrite(ledPin00, HIGH);
        pulselen--;
        if(pulselen<=140+620 && pulselen> 140+620-38.7){
            digitalWrite(ledPin00, HIGH);
            pwm.setPWM(0,0,pulselen-310);  // begin with 450
            delay(35);
        }
        if(pulselen<=140+620-38.7 && pulselen> 140+620-(38.7*2)){
            digitalWrite(ledPin00, HIGH);
            pwm.setPWM(0,0,pulselen-310);
            pwm.setPWM(1,0,pulselen-310+38.7); // begin with 450
            delay(35);
        }
        if(pulselen<=140+620-(38.7*2) && pulselen> 140+620-(38.7*3)){
            digitalWrite(ledPin00, HIGH);
            pwm.setPWM(0,0,pulselen-310);
            pwm.setPWM(1,0,pulselen-310+38.7);
            pwm.setPWM(2,0,pulselen-310+(38.7*2)); // begin with 450

```

```

    delay(35);
}
if(pulselen<=140+620-(38.7*3) && pulselen> 140+620-(38.7*4)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,pulselen-310);
    pwm.setPWM(1,0,pulselen-310+38.7);
    pwm.setPWM(2,0,pulselen-310+(38.7*2));
    pwm.setPWM(3,0,pulselen-310+(38.7*3)); // begin with 450
    delay(35);
}
if(pulselen<=140+620-(38.7*4) && pulselen> 140+620-(38.7*5)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,pulselen-310);
    pwm.setPWM(1,0,pulselen-310+38.7);
    pwm.setPWM(2,0,pulselen-310+(38.7*2));
    pwm.setPWM(3,0,pulselen-310+(38.7*3));
    pwm.setPWM(4,0,pulselen-310+(38.7*4)); // begin with 450
    delay(35);
}
if(pulselen<=140+620-(38.7*5) && pulselen> 140+620-(38.7*6)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,pulselen-310);
    pwm.setPWM(1,0,pulselen-310+38.7);
    pwm.setPWM(2,0,pulselen-310+(38.7*2));
    pwm.setPWM(3,0,pulselen-310+(38.7*3));
    pwm.setPWM(4,0,pulselen-310+(38.7*4));
    pwm.setPWM(5,0,pulselen-310+(38.7*5)); // begin with 450
    delay(35);
}
if(pulselen<=140+620-(38.7*6) && pulselen> 140+620-(38.7*7)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,pulselen-310);
    pwm.setPWM(1,0,pulselen-310+38.7);
    pwm.setPWM(2,0,pulselen-310+(38.7*2));
    pwm.setPWM(3,0,pulselen-310+(38.7*3));
    pwm.setPWM(4,0,pulselen-310+(38.7*4));
    pwm.setPWM(5,0,pulselen-310+(38.7*5));
    pwm.setPWM(6,0,pulselen-310+(38.7*6)); // begin with 450
    delay(35);
}

```

```

if(pulselen<=140+620-(38.7*7) && pulselen> 140+620-(38.7*8)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,pulselen-310); // will be approaching 141.6
    pwm.setPWM(1,0,pulselen-310+38.7);
    pwm.setPWM(2,0,pulselen-310+(38.7*2));
    pwm.setPWM(3,0,pulselen-310+(38.7*3));
    pwm.setPWM(4,0,pulselen-310+(38.7*4));
    pwm.setPWM(5,0,pulselen-310+(38.7*5));
    pwm.setPWM(6,0,pulselen-310+(38.7*6));
    pwm.setPWM(7,0,pulselen-310+(38.7*7)); // begin with 450
    delay(35);
}

if(pulselen<=140+620-(38.7*8) && pulselen> 140+620-(38.7*9)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN); // stay at the end SERVOMIN 140
    pwm.setPWM(1,0,pulselen-310+38.7);
    pwm.setPWM(2,0,pulselen-310+(38.7*2));
    pwm.setPWM(3,0,pulselen-310+(38.7*3));
    pwm.setPWM(4,0,pulselen-310+(38.7*4));
    pwm.setPWM(5,0,pulselen-310+(38.7*5));
    pwm.setPWM(6,0,pulselen-310+(38.7*6));
    pwm.setPWM(7,0,pulselen-310+(38.7*7));
    delay(35);
}

if(pulselen<=140+620-(38.7*9) && pulselen> 140+620-(38.7*10)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN); // stay at the end SERVOMIN 140
    pwm.setPWM(1,0,SERVOMIN);
    pwm.setPWM(2,0,pulselen-310+(38.7*2));
    pwm.setPWM(3,0,pulselen-310+(38.7*3));
    pwm.setPWM(4,0,pulselen-310+(38.7*4));
    pwm.setPWM(5,0,pulselen-310+(38.7*5));
    pwm.setPWM(6,0,pulselen-310+(38.7*6));
    pwm.setPWM(7,0,pulselen-310+(38.7*7));
    delay(35);
}

if(pulselen<=140+620-(38.7*10) && pulselen> 140+620-(38.7*11)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN); // stay at the end SERVOMIN 140
    pwm.setPWM(1,0,SERVOMIN);

```

```

    pwm.setPWM(2,0,SERVOMIN);
    pwm.setPWM(3,0,pulselen-310+(38.7*3));
    pwm.setPWM(4,0,pulselen-310+(38.7*4));
    pwm.setPWM(5,0,pulselen-310+(38.7*5));
    pwm.setPWM(6,0,pulselen-310+(38.7*6));
    pwm.setPWM(7,0,pulselen-310+(38.7*7));
    delay(35);
}

if(pulselen<=140+620-(38.7*11) && pulselen> 140+620-(38.7*12)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN); // stay at the end SERVOMIN 140
    pwm.setPWM(1,0,SERVOMIN);
    pwm.setPWM(2,0,SERVOMIN);
    pwm.setPWM(3,0,SERVOMIN);
    pwm.setPWM(4,0,pulselen-310+(38.7*4));
    pwm.setPWM(5,0,pulselen-310+(38.7*5));
    pwm.setPWM(6,0,pulselen-310+(38.7*6));
    pwm.setPWM(7,0,pulselen-310+(38.7*7));
    delay(35);
}

if(pulselen<=140+620-(38.7*12) && pulselen> 140+620-(38.7*13)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN); // stay at the end SERVOMIN 140
    pwm.setPWM(1,0,SERVOMIN);
    pwm.setPWM(2,0,SERVOMIN);
    pwm.setPWM(3,0,SERVOMIN);
    pwm.setPWM(4,0,SERVOMIN);
    pwm.setPWM(5,0,pulselen-310+(38.7*5));
    pwm.setPWM(6,0,pulselen-310+(38.7*6));
    pwm.setPWM(7,0,pulselen-310+(38.7*7));
    delay(35);
}

if(pulselen<=140+620-(38.7*13) && pulselen> 140+620-(38.7*14)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN); // stay at the end SERVOMIN 140
    pwm.setPWM(1,0,SERVOMIN);
    pwm.setPWM(2,0,SERVOMIN);
    pwm.setPWM(3,0,SERVOMIN);
    pwm.setPWM(4,0,SERVOMIN);
    pwm.setPWM(5,0,SERVOMIN);

```

```

    pwm.setPWM(6,0,pulselen-310+(38.7*6));
    pwm.setPWM(7,0,pulselen-310+(38.7*7));
    delay(35);
}
if(pulselen<=140+620-(38.7*14) && pulselen> 140+620-(38.7*15)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN); // stay at the end SERVOMIN 140
    pwm.setPWM(1,0,SERVOMIN);
    pwm.setPWM(2,0,SERVOMIN);
    pwm.setPWM(3,0,SERVOMIN);
    pwm.setPWM(4,0,SERVOMIN);
    pwm.setPWM(5,0,SERVOMIN);
    pwm.setPWM(6,0,SERVOMIN);
    pwm.setPWM(7,0,pulselen-310+(38.7*7));
    delay(35);
}
if(pulselen<=140+620-(38.7*15) && pulselen> 140+620-(38.7*16)){
    digitalWrite(ledPin00, HIGH);
    pwm.setPWM(0,0,SERVOMIN); // All stay at the end SERVOMIN 140
    pwm.setPWM(1,0,SERVOMIN);
    pwm.setPWM(2,0,SERVOMIN);
    pwm.setPWM(3,0,SERVOMIN);
    pwm.setPWM(4,0,SERVOMIN);
    pwm.setPWM(5,0,SERVOMIN);
    pwm.setPWM(6,0,SERVOMIN);
    pwm.setPWM(7,0,SERVOMIN);
    delay(35);
}
}
}

```

```

void mode01(){
    // do the motion 1
    int count=0;
    while (count<360){
        digitalWrite(ledPin01, HIGH);
        count++;
        int pos=map(count,0,360,SERVOMIN,SERVOMAX);
        pwm.setPWM(0,0,pos);
        pwm.setPWM(1,0,SERVOMAX+SERVOMIN-pos);
    }
}

```

```

    pwm.setPWM(2,0,pos);
    pwm.setPWM(3,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(4,0,pos);
    pwm.setPWM(5,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(6,0,pos);
    pwm.setPWM(7,0,SERVOMAX+SERVOMIN-pos);
    delay(35);
}
int countBack=360;
while (countBack>0){
    digitalWrite(ledPin01, HIGH);
    countBack--;
    int pos=map(countBack,360,0,SERVOMAX,SERVOMIN);
    pwm.setPWM(0,0,pos);
    pwm.setPWM(1,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(2,0,pos);
    pwm.setPWM(3,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(4,0,pos);
    pwm.setPWM(5,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(6,0,pos);
    pwm.setPWM(7,0,SERVOMAX+SERVOMIN-pos);
    delay(35);
}
count=0;
while (count<360){
    digitalWrite(ledPin01, HIGH);
    count++;
    int pos=map(count,0,360,SERVOMIN,SERVOMAX);
    pwm.setPWM(0,0,pos);
    pwm.setPWM(1,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(2,0,pos);
    pwm.setPWM(3,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(4,0,pos);
    pwm.setPWM(5,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(6,0,pos);
    pwm.setPWM(7,0,SERVOMAX+SERVOMIN-pos);
    delay(35);
}
countBack=360;
while (countBack>0){

```



```

digitalWrite(ledPin01, HIGH);
countBack--;
int pos=map(countBack,360,0,SERVOMAX,SERVOMIN);
pwm.setPWM(0,0,pos);
pwm.setPWM(1,0,SERVOMAX+SERVOMIN-pos);
pwm.setPWM(2,0,pos);
pwm.setPWM(3,0,SERVOMAX+SERVOMIN-pos);
pwm.setPWM(4,0,pos);
pwm.setPWM(5,0,SERVOMAX+SERVOMIN-pos);
pwm.setPWM(6,0,pos);
pwm.setPWM(7,0,SERVOMAX+SERVOMIN-pos);
delay(35);
}
count=0;
while (count<360){
    digitalWrite(ledPin01, HIGH);
    count++;
    int pos=map(count,0,360,SERVOMIN,SERVOMAX);
    pwm.setPWM(0,0,pos);
    pwm.setPWM(1,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(2,0,pos);
    pwm.setPWM(3,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(4,0,pos);
    pwm.setPWM(5,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(6,0,pos);
    pwm.setPWM(7,0,SERVOMAX+SERVOMIN-pos);
    delay(35);
}
countBack=360;
while (countBack>0){
    digitalWrite(ledPin01, HIGH);
    countBack--;
    int pos=map(countBack,360,0,SERVOMAX,SERVOMIN);
    pwm.setPWM(0,0,pos);
    pwm.setPWM(1,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(2,0,pos);
    pwm.setPWM(3,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(4,0,pos);
    pwm.setPWM(5,0,SERVOMAX+SERVOMIN-pos);
    pwm.setPWM(6,0,pos);

```

```

    pwm.setPWM(7,0,SERVOMAX+SERVOMIN-pos);
    delay(35);
}
countBack=360;
while (countBack>0){
    digitalWrite(ledPin01, HIGH);
    countBack--;
    int pos=map(countBack,360,0,SERVOMAX,SERVOMIN);
    pwm.setPWM(1,0,pos);
    pwm.setPWM(3,0,pos);
    pwm.setPWM(5,0,pos);
    pwm.setPWM(7,0,pos);
    delay(40);
}
}

void mode02(){
    // do the motion 1
    int count=0;
    while (count<360){
        digitalWrite(ledPin02, HIGH);
        count++;
        int pos=map(count,0,360,SERVOMIN,SERVOMAX);
        pwm.setPWM(0,0,pos);
        pwm.setPWM(2,0,pos);
        pwm.setPWM(4,0,pos);
        pwm.setPWM(6,0,pos);
        delay(45);
    }
    count=0;
    while (count<360){
        digitalWrite(ledPin02, HIGH);
        count++;
        int pos=map(count,0,360,SERVOMIN,SERVOMAX);
        pwm.setPWM(1,0,pos);
        pwm.setPWM(3,0,pos);
        pwm.setPWM(5,0,pos);
        pwm.setPWM(7,0,pos);
        delay(45);
    }
}

```

```

int countBack=360;
while (countBack>0){
    digitalWrite(ledPin02, HIGH);
    countBack--;
    int pos=map(countBack,360,0,SERVOMAX,SERVOMIN);
    pwm.setPWM(0,0,pos);
    pwm.setPWM(2,0,pos);
    pwm.setPWM(4,0,pos);
    pwm.setPWM(6,0,pos);
    delay(45);
}
countBack=360;
while (countBack>0){
    digitalWrite(ledPin02, HIGH);
    countBack--;
    int pos=map(countBack,360,0,SERVOMAX,SERVOMIN);
    pwm.setPWM(1,0,pos);
    pwm.setPWM(3,0,pos);
    pwm.setPWM(5,0,pos);
    pwm.setPWM(7,0,pos);
    delay(45);
}
}

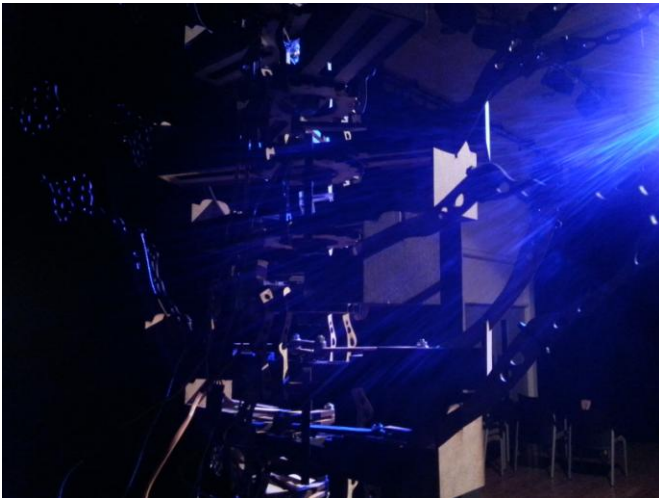
void mode03(){
    // do the motion 1
    int count=0;
    while (count<360){
        digitalWrite(ledPin03, HIGH);
        count++;
        int pos=map(count,0,360,SERVOMIN,SERVOMAX);
        pwm.setPWM(0,0,pos);
        pwm.setPWM(1,0,pos);
        pwm.setPWM(2,0,pos);
        pwm.setPWM(3,0,pos);
        pwm.setPWM(4,0,pos);
        pwm.setPWM(5,0,pos);
        pwm.setPWM(6,0,pos);
        pwm.setPWM(7,0,pos);
        delay(65);
    }
}

```

```

}
int countBack=360;
while (countBack>0){
  digitalWrite(ledPin03, HIGH);
  countBack--;
  int pos=map(countBack,360,0,SERVOMAX,SERVOMIN);
  pwm.setPWM(0,0,pos);
  pwm.setPWM(1,0,pos);
  pwm.setPWM(2,0,pos);
  pwm.setPWM(3,0,pos);
  pwm.setPWM(4,0,pos);
  pwm.setPWM(5,0,pos);
  pwm.setPWM(6,0,pos);
  pwm.setPWM(7,0,pos);
  delay(65);
}
}

```



Before the exhibition, I tested various visual effects by projecting colours onto the artwork (see the figure above). The MDFs showed good results when some colours were projected onto its surface. Through *Processing*, the projection was also designed to be fully responsive to the environmental changes. This made the installation more ‘performance-like’ and suggested that utilizing projection mapping design with MDF-assembled objects a potential field to be explore in the future. The *Processing* code for the projection is:

```

// Processing code for projection of Botanical Universe

int x;
int y;
int z;
int i;
int j;
int k;
PImage image;
int timeGap = 5000; //150000 for exhibition (150 seconds for one transformation)

void setup() {
    size(1024, 768);
    smooth();
    frameRate(60); // 2 for exhibition
    image= loadImage("ProjectionCover2.png");
}

void draw() {
    int time= millis();
    float percent = time*0.00000006944444444; // 1/14400000
    // println("time= " + time);
    println("time= " + percent + " %");
    // round 1
    if (time>0 && time<timeGap*1) {
        BGBtoGRG();
    }
    if (time>timeGap*1 && time<timeGap*2) {
        GRGtoRBR();
    }
    if (time>timeGap*2 && time<timeGap*3) {
        RBRtoPYP();
    }
    if (time>timeGap*3 && time<timeGap*4) {
        PYPtoCPC() ;
    }
    if (time>timeGap*4 && time<timeGap*5) {
        CPCtoYCY() ;
    }
}

```

```

if (time>timeGap*5 && time<timeGap*6) {
    YCYtoBGB() ;
}
// round 2
if (time>timeGap*6 && time<timeGap*7) {
    BGBtoGRG();
}
if (time>timeGap*7 && time<timeGap*8) {
    GRGtoRBR();
}
if (time>timeGap*8 && time<timeGap*9) {
    RBRtoPYP();
}
if (time>timeGap*9 && time<timeGap*10) {
    PYPtoCPC() ;
}
if (time>timeGap*10 && time<timeGap*11) {
    CPCtoYCY() ;
}
if (time>timeGap*11 && time<timeGap*12) {
    YCYtoBGB() ;
}
// round 3
if (time>timeGap*12 && time<timeGap*13) {
    BGBtoGRG();
}
if (time>timeGap*13 && time<timeGap*14) {
    GRGtoRBR();
}
if (time>timeGap*14 && time<timeGap*15) {
    RBRtoPYP();
}
if (time>timeGap*15 && time<timeGap*16) {
    PYPtoCPC() ;
}
if (time>timeGap*16 && time<timeGap*17) {
    CPCtoYCY() ;
}
if (time>timeGap*17 && time<timeGap*18) {
    YCYtoBGB() ;
}

```

```

}
// round 4
if (time>timeGap*18 && time<timeGap*19) {
    BGBtoGRG();
}
if (time>timeGap*19 && time<timeGap*20) {
    GRGtoRBR();
}
if (time>timeGap*20 && time<timeGap*21) {
    RBRtoPYP();
}
if (time>timeGap*21 && time<timeGap*22) {
    PYPtoCPC() ;
}
if (time>timeGap*22 && time<timeGap*23) {
    CPCtoYCY() ;
}
if (time>timeGap*23 && time<timeGap*24) { // 3600000
    YCYtoBGB() ;
}
// round 5
if (time>timeGap*24 && time<timeGap*25) {
    BGBtoGRG();
}
if (time>timeGap*25 && time<timeGap*26) {
    GRGtoRBR();
}
if (time>timeGap*26 && time<timeGap*27) {
    RBRtoPYP();
}
if (time>timeGap*27 && time<timeGap*28) {
    PYPtoCPC() ;
}
if (time>timeGap*28 && time<timeGap*29) {
    CPCtoYCY() ;
}
if (time>timeGap*29 && time<timeGap*30) {
    YCYtoBGB() ;
}
// round 6

```

```

if (time>timeGap*30 && time<timeGap*31) {
    BGBtoGRG();
}
if (time>timeGap*31 && time<timeGap*32) {
    GRGtoRBR();
}
if (time>timeGap*32 && time<timeGap*33) {
    RBRtoPYP();
}
if (time>timeGap*33 && time<timeGap*34) {
    PYPtoCPC() ;
}
if (time>timeGap*34 && time<timeGap*35) {
    CPCtoYCY() ;
}
if (time>timeGap*35 && time<timeGap*36) {
    YCYtoBGB() ;
}
// round 7
if (time>timeGap*36 && time<timeGap*37) {
    BGBtoGRG();
}
if (time>timeGap*37 && time<timeGap*38) {
    GRGtoRBR();
}
if (time>timeGap*38 && time<timeGap*39) {
    RBRtoPYP();
}
if (time>timeGap*39 && time<timeGap*40) {
    PYPtoCPC() ;
}
if (time>timeGap*40 && time<timeGap*41) {
    CPCtoYCY() ;
}
if (time>timeGap*41 && time<timeGap*42) {
    YCYtoBGB() ;
}
// round 8
if (time>timeGap*42 && time<timeGap*43) {
    BGBtoGRG();
}

```



```

}
if (time>timeGap*43 && time<timeGap*44) {
    GRGtoRBR();
}
if (time>timeGap*44 && time<timeGap*45) {
    RBRtoPYP();
}
if (time>timeGap*45 && time<timeGap*46) {
    PYPtoCPC() ;
}
if (time>timeGap*46 && time<timeGap*47) {
    CPCtoYCY() ;
}
if (time>timeGap*47 && time<timeGap*48) { // 7200000
    YCYtoBGB() ;
}
// round 9
if (time>timeGap*48 && time<timeGap*49) {
    BGBtoGRG();
}
if (time>timeGap*49 && time<timeGap*50) {
    GRGtoRBR();
}
if (time>timeGap*50 && time<timeGap*51) {
    RBRtoPYP();
}
if (time>timeGap*51 && time<timeGap*52) {
    PYPtoCPC() ;
}
if (time>timeGap*52 && time<timeGap*53) {
    CPCtoYCY() ;
}
if (time>timeGap*53 && time<timeGap*54) {
    YCYtoBGB() ;
}
// round 10
if (time>timeGap*54 && time<timeGap*55) {
    BGBtoGRG();
}
if (time>timeGap*55 && time<timeGap*56) {

```

```

    GRGtoRBR();
}
if (time>timeGap*56 && time<timeGap*57) {
    RBRtoPYP();
}
if (time>timeGap*57 && time<timeGap*58) {
    PYPtoCPC() ;
}
if (time>timeGap*58 && time<timeGap*59) {
    CPCtoYCY() ;
}
if (time>timeGap*59 && time<timeGap*60) {
    YCYtoBGB() ;
}
// round 11
if (time>timeGap*60 && time<timeGap*61) {
    BGBtoGRG();
}
if (time>timeGap*61 && time<timeGap*62) {
    GRGtoRBR();
}
if (time>timeGap*62 && time<timeGap*63) {
    RBRtoPYP();
}
if (time>timeGap*63 && time<timeGap*64) {
    PYPtoCPC() ;
}
if (time>timeGap*64 && time<timeGap*65) {
    CPCtoYCY() ;
}
if (time>timeGap*65 && time<timeGap*66) {
    YCYtoBGB() ;
}
// round 12
if (time>timeGap*66 && time<timeGap*67) {
    BGBtoGRG();
}
if (time>timeGap*67 && time<timeGap*68) {
    GRGtoRBR();
}

```

```

if (time>timeGap*68 && time<timeGap*69) {
    RBRtoPYP();
}
if (time>timeGap*69 && time<timeGap*70) {
    PYPtoCPC() ;
}
if (time>timeGap*70 && time<timeGap*71) {
    CPCtoYCY() ;
}
if (time>timeGap*71 && time<timeGap*72) { // 10800000
    YCYtoBGB() ;
}
// round 13
if (time>timeGap*72 && time<timeGap*73) {
    BGBtoGRG();
}
if (time>timeGap*73 && time<timeGap*74) {
    GRGtoRBR();
}
if (time>timeGap*74 && time<timeGap*75) {
    RBRtoPYP();
}
if (time>timeGap*75 && time<timeGap*76) {
    PYPtoCPC() ;
}
if (time>timeGap*76 && time<timeGap*77) {
    CPCtoYCY() ;
}
if (time>timeGap*77 && time<timeGap*78) {
    YCYtoBGB() ;
}
// round 14
if (time>timeGap*78 && time<timeGap*79) {
    BGBtoGRG();
}
if (time>timeGap*79 && time<timeGap*80) {
    GRGtoRBR();
}
if (time>timeGap*80 && time<timeGap*81) {
    RBRtoPYP();
}

```

```

}
if (time>timeGap*81 && time<timeGap*82) {
    PYPtoCPC() ;
}
if (time>timeGap*82 && time<timeGap*83) {
    CPCtoYCY() ;
}
if (time>timeGap*83 && time<timeGap*84) {
    YCYtoBGB() ;
}
// round 15
if (time>timeGap*84 && time<timeGap*85) {
    BGBtoGRG();
}
if (time>timeGap*85 && time<timeGap*86) {
    GRGtoRBR();
}
if (time>timeGap*86 && time<timeGap*87) {
    RBRtoPYP();
}
if (time>timeGap*87 && time<timeGap*88) {
    PYPtoCPC() ;
}
if (time>timeGap*88 && time<timeGap*89) {
    CPCtoYCY() ;
}
if (time>timeGap*89 && time<timeGap*90) {
    YCYtoBGB() ;
}
// round 16
if (time>timeGap*90 && time<timeGap*91) {
    BGBtoGRG();
}
if (time>timeGap*91 && time<timeGap*92) {
    GRGtoRBR();
}
if (time>timeGap*92 && time<timeGap*93) {
    RBRtoPYP();
}
if (time>timeGap*93 && time<timeGap*94) {

```

```

    PYPtoCPC() ;
}
if (time>timeGap*94 && time<timeGap*95) {
    CPCtoYCY() ;
}
if (time>timeGap*95 && time<timeGap*96) { // 14400000
    YCYtoBGB() ;
}
    image(image, 0, 0, width, height);
}

void BGB() {
    background(0);
    noStroke();
    fill(0, 0, 255);
    rect(0, 0, width/3, height, 30);
    fill(0, 255, 0);
    rect((width/3)*1, 0, width/3, height, 30);
    fill(0, 0, 255);
    rect((width/3)*2, 0, width/3, height, 30);
}

void GRG() {
    background(0);
    noStroke();
    fill(0, 255, 0);
    rect(0, 0, width/3, height, 30);
    fill(255, 0, 0);
    rect((width/3)*1, 0, width/3, height, 30);
    fill(0, 255, 0);
    rect((width/3)*2, 0, width/3, height, 30);
}

void RBR() {
    background(0);
    noStroke();
    fill(255, 0, 0);
    rect(0, 0, width/3, height, 30);
    fill(0, 0, 255);
    rect((width/3)*1, 0, width/3, height, 30);
    fill(255, 0, 0);

```

```

    rect((width/3)*2, 0, width/3, height, 30);
}

void PYP() {
    background(0);
    noStroke();
    fill(255, 0, 255);
    rect(0, 0, width/3, height, 30);
    fill(255, 255, 0);
    rect((width/3)*1, 0, width/3, height, 30);
    fill(255, 0, 255);
    rect((width/3)*2, 0, width/3, height, 30);
}

void CPC() {
    background(0);
    noStroke();
    fill(0, 255, 255);
    rect(0, 0, width/3, height, 30);
    fill(255, 0, 255);
    rect((width/3)*1, 0, width/3, height, 30);
    fill(0, 255, 255);
    rect((width/3)*2, 0, width/3, height, 30);
}

void YCY() {
    background(0);
    noStroke();
    fill(255, 255, 0);
    rect(0, 0, width/3, height, 30);
    fill(0, 255, 255);
    rect((width/3)*1, 0, width/3, height, 30);
    fill(255, 255, 0);
    rect((width/3)*2, 0, width/3, height, 30);
}

void BGBtoGRG() {
    k=0;
    background(0);
    noStroke();
    fill(0, x, 255-x);
    rect(0, 0, width/3, height, 30);
    fill(x, 255-x, 0);

```

```

rect((width/3)*1, 0, width/3, height, 30);
fill(0, x, 255-x);
rect((width/3)*2, 0, width/3, height, 30);
if (x<255) {
    x++;
}
print("x= ");
println(x);
}

void GRGtoRBR() {
    x=0;
    background(0);
    noStroke();
    fill(y, 255-y, 0);
    rect(0, 0, width/3, height, 30);
    fill(255-y, 0, y);
    rect((width/3)*1, 0, width/3, height, 30);
    fill(y, 255-y, 0);
    rect((width/3)*2, 0, width/3, height, 30);
    if (y<255) {
        y++;
    }
    print("y= ");
    println(y);
}

void RBRtoPYP() {
    y=0;
    background(0);
    noStroke();
    fill(255, 0, z);
    rect(0, 0, width/3, height, 30);
    fill(z, z, 255-z);
    rect((width/3)*1, 0, width/3, height, 30);
    fill(255, 0, z);
    rect((width/3)*2, 0, width/3, height, 30);
    if (z<255) {
        z++;
    }
    print("z= ");
    println(z);
}

```

```
}
```

```
void PYPtoCPC() {  
  z=0;  
  background(0);  
  noStroke();  
  fill(255-i, i, 255);  
  rect(0, 0, width/3, height, 30);  
  fill(255, 255-i, i);  
  rect((width/3)*1, 0, width/3, height, 30);  
  fill(255-i, i, 255);  
  rect((width/3)*2, 0, width/3, height, 30);  
  if (i<255) {  
    i++;  
  }  
  print("i= ");  
  println(i);  
}
```

```
void CPCtoYCY() {  
  i=0;  
  background(0);  
  noStroke();  
  fill(j, 255, 255-j);  
  rect(0, 0, width/3, height, 30);  
  fill(255-j, j, 255);  
  rect((width/3)*1, 0, width/3, height, 30);  
  fill(j, 255, 255-j);  
  rect((width/3)*2, 0, width/3, height, 30);  
  if (j<255) {  
    j++;  
  }  
  print("j= ");  
  println(j);  
}
```

```
void YCYtoBGB() {  
  j=0;  
  background(0);  
  noStroke();
```



```

fill(255-k, 255-k, k);
rect(0, 0, width/3, height, 30);
fill(0, 255, 255-k);
rect((width/3)*1, 0, width/3, height, 30);
fill(255-k, 255-k, k);
rect((width/3)*2, 0, width/3, height, 30);
if (k<255) {
    k++;
}
print("k= ");
println(k);
}

```

The supporting base and the skeleton that held the whole mechanisms were actually designed later right before the artwork was exhibited. In other words, the making of *Botanical Universe* suggests that it is more controllable to start building the core object (i.e. the responsive ticking mechanism) when building such a complex artefact with various mechanisms and sensors. This also suggests new media artist/maker start working on the main technology, and by expanding, duplicating a simple piece of technology, one may develop complex compositions and ideas.

16. The Flower of Time V.2

Based on the experience gained in *Botanical Universe*, I started the making of *The Flower of Time V.2* with building a testing mechanism by laser-cut acrylic sheets (see the following figure). This acrylic prototype helped me understand the measurement of each components and intersecting angles for best result. Several versions were built and tested before a satisfying mechanism was completed. The final version could open and close smoothly with the most diverse range.



When designing the final mechanism, *Adobe Illustrator* was helpful for redrawing the contour of any object. By locking the original contour and drawing a new contour without moving the joints (screw holes), I could replace the testing blueprint with a more designed work. This made the mechanism functional but more visual attractive. The following image shows a re-designed version. This technique can be easily adopted for artists/makers to construct more ‘aesthetic mechanism’ in future artworks.



In the design of the mechanism, the rotating gear of the servomotor was set in the center position to reduce friction. The acrylic sheets performed well as they have quite a polished surface. I suggest that future artists/makers use the ni-lock screws to ensure the joints are secured. The *Arduino* and *Processing* code of *The Flower of Time V.2* are listed as following. The basic idea of the *Arduino* code is to receive the time readings and ‘performing modes’ from the *Processing* code through serial communication, and tick the mechanism based on that time readings and modes.

The *Arduino* code of *The Flower of Time V.2* is:

```
#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>
byte pos[5];
Adafruit_PWMServoDriver pwm = Adafruit_PWMServoDriver();
#define SERVOMIN 160 // this is the 'minimum' pulse length count (out of 4096)
#define SERVOMAX 300 // this is the 'maximum' pulse length count (out of 4096)
// Parallax Standard Servo 100 - 450
// TowerPro MG995 Servo 100 - 450
boolean motorReset = false;
// When it is SERVOMIN, the size of flower is the MAX
// When it is SERVOMAX, the size of flower is the MIN
// our servo # counter
uint8_t servonum = 0;

void setup() {
  // initialize serial:
  Serial.begin(9600);
  pwm.begin();
  pwm.setPWMFreq(50); // Analog servos run at ~60 Hz updates// MG90S== 50Hz
  for (int i=0;i<4;i++){
    pos[i]=0;
  }
  establishContact(); // send a byte to establish contact until receiver responds
}

void setServoPulse(uint8_t n, double pulse) {
```

```

double pulselength;
pulselength = 1000000;    // 1,000,000 us per second
pulselength /= 50;        // 50 Hz for MG90S
Serial.print(pulselength);
Serial.println(" us per period");
pulselength /= 4096;      // 12 bits of resolution
Serial.print(pulselength);
Serial.println(" us per bit");
pulse *= 1000;
pulse /= pulselength;
Serial.println(pulse);
pwm.setPWM(n, 0, pulse);
}

void loop() {
  uint16_t TickMode;
  uint16_t daysTick;
  uint16_t hoursTick;
  uint16_t minsTick;
  uint16_t secsTick;
  // if there's any serial available, read it:
  while (Serial.available() > 0) {
    // look for the next valid integer in the incoming serial stream:
    // get the mode
    pos[0]= Serial.parseInt();
    // get days
    pos[1]= Serial.parseInt();
    // get hours
    pos[2]= Serial.parseInt();
    // get mins
    pos[3]= Serial.parseInt();
    // get secs
    pos[4]= Serial.parseInt();

    // look for the newline. That's the end of your sentence:
    if (Serial.read() == '\n') {
      //Serial.write(pos[0]); // if I want to test if Processing receive it
      Serial.flush();        //flush the output buffer
      TickMode = pos[0];
    }
  }
}

```

```

    if(TickMode == 0){
        daysTick = map(pos[1], 0,180,SERVOMIN,SERVOMAX);
        hoursTick = map(pos[2], 0,180,SERVOMIN,SERVOMAX);
        minsTick = map(pos[3], 0,180,SERVOMIN,SERVOMAX);
        secsTick = map(pos[4], 0,180,SERVOMIN,SERVOMAX);
        pwm.setPWM(4, 0, daysTick);
        pwm.setPWM(3, 0, hoursTick);
        pwm.setPWM(2, 0, minsTick);
        pwm.setPWM(1, 0, secsTick);
        Serial.flush();    //flush the output buffer
    }
    else if (TickMode == 1){
        wave();
        // turn off the Serial for the motors to finish their job
        Serial.end();
        Serial.begin(9600);
    }
    else if (TickMode == 2){
        twoGroups();
        // turn off the Serial for the motors to finish their job
        Serial.end();
        Serial.begin(9600);
    }
    else if (TickMode == 3){
        // turn off the Serial for the motors to finish their job
        Serial.end();
        Serial.begin(9600);
    }
}
}
}

void turnTogether(){
    for (uint16_t pulselen = SERVOMIN; pulselen < SERVOMAX; pulselen+=2) {
        pwm.setPWM(1, 0, pulselen);
        pwm.setPWM(2, 0, pulselen);
        pwm.setPWM(3, 0, pulselen);
        pwm.setPWM(4, 0, pulselen);
        delay(30);
    }
}

```

```

// delay(2000); // I cannot delay here, because it delays the next Mode!
for (uint16_t pulselen = SERVOMAX; pulselen > SERVOMIN; pulselen-=2) {
    pwm.setPWM(1, 0, pulselen);
    pwm.setPWM(2, 0, pulselen);
    pwm.setPWM(3, 0, pulselen);
    pwm.setPWM(4, 0, pulselen);
    delay(30);
}
// delay(2000); // I cannot delay here, because it delays the next Mode!
}

```

```

void twoGroups(){
    // go to the ready position first (0,0,0,0)
    pwm.setPWM(1, 0, SERVOMIN); // 0
    delay(20);
    pwm.setPWM(2, 0, SERVOMIN); // 0
    delay(20);
    pwm.setPWM(3, 0, SERVOMIN); // 0
    delay(20);
    pwm.setPWM(4, 0, SERVOMIN); // 0
    delay(20);

    for (uint16_t pulselen = SERVOMIN; pulselen < SERVOMAX; pulselen+=2) {
        pwm.setPWM(1, 0, pulselen);
        pwm.setPWM(3, 0, pulselen);
        delay(20);
    }
    for (uint16_t pulselen = SERVOMAX; pulselen > SERVOMIN; pulselen-=2) {
        pwm.setPWM(1, 0, pulselen);
        pwm.setPWM(3, 0, pulselen);
        delay(20);
    }
    for (uint16_t pulselen = SERVOMIN; pulselen < SERVOMAX; pulselen+=2) {
        pwm.setPWM(2, 0, pulselen);
        pwm.setPWM(4, 0, pulselen);
        delay(20);
    }
    for (uint16_t pulselen = SERVOMAX; pulselen > SERVOMIN; pulselen-=2) {
        pwm.setPWM(2, 0, pulselen);
        pwm.setPWM(4, 0, pulselen);
    }
}

```

```

    delay(20);
}
}

void wave(){
    // wave motion
    // The motor position as below
    // 3 is the biggest value, 0 is the lowest value
    // motor1- motor2- motor3- motor 4
    // 3 2 1 0
    // 2 3 2 1
    // 1 2 3 2
    // 0 1 2 3
    // 1 0 1 2
    // 2 1 0 1
    // 3 2 1 0

    // one routine is 50*6=300 steps
    uint16_t pulselen= 0;
    uint16_t MovingGap = (SERVOMAX-SERVOMIN)/3; // 50
    while(pulselen<=MovingGap*6){
        pulselen+=2;
        delay(30);
        if(pulselen>0 && pulselen <=MovingGap*1){
            pwm.setPWM(1,0,SERVOMAX-pulselen); // 3 ->2
            pwm.setPWM(2,0,SERVOMIN+((SERVOMAX-SERVOMIN)/3)*2+pulselen); // 2 -> 3
            pwm.setPWM(3, 0, SERVOMIN+((SERVOMAX-SERVOMIN)/3)*1+pulselen); //1 -> 2
            pwm.setPWM(4, 0, SERVOMIN+pulselen); // 0 -> 1
        }
        if(pulselen>MovingGap*1 && pulselen <=MovingGap*2){
            pwm.setPWM(1,0,SERVOMIN+((SERVOMAX-SERVOMIN)/3)*2-(pulselen-MovingGap)); // 2 -> 1
            pwm.setPWM(2,0,SERVOMAX-(pulselen-MovingGap)); // 3 ->2
            pwm.setPWM(3, 0, SERVOMIN+((SERVOMAX-SERVOMIN)/3)*2+(pulselen-MovingGap)); //2 ->3
            pwm.setPWM(4, 0, SERVOMIN+((SERVOMAX-SERVOMIN)/3)*1+(pulselen-MovingGap)); // 1 ->2
        }
        if(pulselen>MovingGap*2 && pulselen <=MovingGap*3){
            pwm.setPWM(1,0,SERVOMIN+((SERVOMAX-SERVOMIN)/3)*1-(pulselen-(MovingGap*2))); // 1
            ->0
            pwm.setPWM(2,0,SERVOMIN+((SERVOMAX-SERVOMIN)/3)*2-(pulselen-(MovingGap*2))); // 2 ->

```

```

    pwm.setPWM(3, 0, SERVOMAX-(pulselen-(MovingGap*2))); //3 -> 2
    pwm.setPWM(4, 0, SERVOMIN+((SERVOMAX-SERVOMIN)/3)*2+(pulselen-(MovingGap*2))); // 2
-> 3
}
if(pulselen>MovingGap*3 && pulselen <=MovingGap*4){
    pwm.setPWM(1,0,SERVOMIN+(pulselen-(MovingGap*3))); // 0 ->1
    pwm.setPWM(2,0,SERVOMIN+((SERVOMAX-SERVOMIN)/3)*1-(pulselen-(MovingGap*3))); // 1 ->
0
    pwm.setPWM(3, 0, SERVOMIN+((SERVOMAX-SERVOMIN)/3)*2-(pulselen-(MovingGap*3))); //2
-> 1
    pwm.setPWM(4, 0, SERVOMAX-(pulselen-(MovingGap*3))); // 3 -> 2
}
if(pulselen>MovingGap*4 && pulselen <=MovingGap*5){
    pwm.setPWM(1,0,SERVOMIN+((SERVOMAX-SERVOMIN)/3)*1+(pulselen-(MovingGap*4))); // 1
->2
    pwm.setPWM(2,0,SERVOMIN+(pulselen-(MovingGap*4))); // 0 -> 1
    pwm.setPWM(3, 0, SERVOMIN+((SERVOMAX-SERVOMIN)/3)*1-(pulselen-(MovingGap*4))); //1
-> 0
    pwm.setPWM(4, 0, SERVOMIN+((SERVOMAX-SERVOMIN)/3)*2-(pulselen-(MovingGap*4))); // 2
-> 1
}
if(pulselen>MovingGap*5 && pulselen <=MovingGap*6){
    pwm.setPWM(1,0,SERVOMIN+((SERVOMAX-SERVOMIN)/3)*2+(pulselen-(MovingGap*5))); // 2
->3
    pwm.setPWM(2,0,SERVOMIN+((SERVOMAX-SERVOMIN)/3)*1+(pulselen-(MovingGap*5))); // 1 ->
2
    pwm.setPWM(3, 0, SERVOMIN+(pulselen-(MovingGap*5))); //0 -> 1
    pwm.setPWM(4, 0, SERVOMIN+((SERVOMAX-SERVOMIN)/3)*1-(pulselen-(MovingGap*5))); // 1
-> 0
}
}
}

void establishContact() {
    while (Serial.available()<= 0) {
        Serial.print('A'); // send a capital A
        delay(300);
    }
}
}

```


The main idea of the following *Processing* code is to decide the ‘performing mode’ and send to *Arduino* UNO through serial communication. The *Processing* code of *The Flower of Time* V.2 is:

```
import processing.serial.*;
Serial port;
Boolean sendData =false;
int month;
int days;
int hours;
int mins;
int secs;
boolean firstContact = false;          // Whether we've heard from the microcontroller
int waitTime = (int) (1 * 1000); // 1.0 seconds
int startTime;

void setup() {
    // the int array called "numbers" will carry 4 differnt ints
    size(1280, 900);
    //size(300, 200);
    noStroke();
    colorMode(HSB, 366);
    println("Available serial ports:");
    println(Serial.list());
    port = new Serial(this, Serial.list()[5], 9600);
    // port.bufferUntil( '\n');
}

void draw() {
    month = month();
    //days = day();
    days = 78;
    hours = hour(); // Values from 0 - 23
    mins = minute(); // Values from 0 - 59
    secs = second(); // Values from 0 - 59
    if (firstContact == true) {
```

```

if (TimeToSend()) {
    //println(waitTime/1000 + " seconds have transpired!");
    //draw the 4 rects on screen for projection
    //drawRects();
    if ((mins%5 ==1)||(mins%5 ==3)||(mins%5 ==4)) {
        //Normal Mode
        drawRects();
        println("day=" + days + " hours="+hours+" mins="+mins+" secs="+secs);
        // do the mappings for Arduino
        if (hours>=0 && hours<12) {
            hours =int(map(hours, 0, 11, 180, 5));
        } else {
            hours=int(map(hours, 12, 23, 0, 175));
        }
        if (mins>=0 && mins <30) {
            mins =int(map(mins, 0, 29, 180, 5));
        } else {
            mins =int(map(mins, 30, 59, 0, 175));
        }
        if (secs>=0 && secs< 30) {
            secs=int(map(secs, 0, 29, 180, 5));
        } else {
            secs=int(map(secs, 30, 59, 0, 175));
        }
        port.clear();
        String total = "";
        String mode = str(0);
        String d = str(days);
        String h = str(hours);
        String m = str(mins);
        String s = str(secs);
        total= total+mode+" "+d+" "+h+" "+m+" "+s;
        // println(total);
        port.write(total+"\n");    //the second byte is the actual value.
    } else if (mins%5 ==0) {
        // Wave Mode
        drawWaveRects();
        println("day=" + days + " hours="+hours+" mins="+mins+" secs="+secs);
        // do the mappings for Arduino
        if (hours>=0 && hours<12) {

```

```

        hours =int(map(hours, 0, 11, 180, 5));
    } else {
        hours=int(map(hours, 12, 23, 0, 175));
    }
    if (mins>=0 && mins <30) {
        mins =int(map(mins, 0, 29, 180, 5));
    } else {
        mins =int(map(mins, 30, 59, 0, 175));
    }
    if (secs>=0 && secs< 30) {
        secs=int(map(secs, 0, 29, 180, 5));
    } else {
        secs=int(map(secs, 30, 59, 0, 175));
    }
    port.clear();
    String total = "";
    String mode = str(1);
    String d = str(days);
    String h = str(hours);
    String m = str(mins);
    String s = str(secs);
    total= total+mode+" "+d+" "+h+" "+m+" "+s;
    // println(total);
    port.write(total+"\n");    //the second byte is the actual value.
} else if (mins%5 ==2) {
    // TwoGroupsMode
    drawTwoGroupRects();

    println("day=" + days + " hours="+hours+" mins="+mins+" secs="+secs);
    // do the mappings for Arduino
    if (hours>=0 && hours<12) {
        hours =int(map(hours, 0, 11, 180, 5));
    } else {
        hours=int(map(hours, 12, 23, 0, 175));
    }
    if (mins>=0 && mins <30) {
        mins =int(map(mins, 0, 29, 180, 5));
    } else {
        mins =int(map(mins, 30, 59, 0, 175));
    }
}

```

```

    }
    if (secs>=0 && secs< 30) {
        secs=int(map(secs, 0, 29, 180, 5));
    } else {
        secs=int(map(secs, 30, 59, 0, 175));
    }
    port.clear();
    String total = "";
    String mode = str(2);
    String d = str(days);
    String h = str(hours);
    String m = str(mins);
    String s = str(secs);
    total= total+mode+", "+d+", "+h+", "+m+", "+s;
    // println(total);
    port.write(total+"\n");    //the second byte is the actual value.
}
startTime = millis();
}
}
}

void serialEvent(Serial myPort) {
    // read a byte from the serial port:
    //  char inByte = (char) myPort.read();
    int inByte = myPort.read();
    println ("in Serial", inByte);
    // if this is the first byte received, and it's an A,
    // clear the serial buffer and note that you've
    // had first contact from the microcontroller.
    // Otherwise, add the incoming byte to the array:
    if (firstContact == false) {
        if (inByte == 'A') {
            myPort.clear();        // clear the serial port buffer
            firstContact = true;    // you've had first contact from the microcontroller
        }
    }
}

boolean TimeToSend() {
    return millis() - startTime > waitTime;
}

```

```
}
```

```
void drawRects() {  
    //draw secs rect  
    fill(map(secs, 0, 60, 0, 366), 366, 366);  
    rect(0, 0, width, height/4);  
    //draw mins rect  
    fill(map(mins, 0, 60, 0, 366), 366, 366);  
    rect(0, height/4, width, height/4);  
    //draw hours rect  
    fill(map(hours, 0, 24, 0, 366), 366, 366);  
    rect(0, height/2, width, height/4);  
    //draw days rect  
    fill(map(78, 0, 366, 0, 366), 366, 366);  
    rect(0, (height/4)*3, width, height/4);  
}
```

```
void drawTwoGroupRects() {  
    // 0,1 , 4 , 5 ,8,9,12,13,16,17...  
    if (secs%4==0 || secs%4==1) {  
        //draw secs rect  
        fill(map(secs, 0, 60, 0, 366), 366, 366);  
        rect(0, 0, width, height/4);  
        //draw mins rect  
        fill(map(mins, 0, 60, 0, 366), 366, 366);  
        rect(0, height/4, width, height/4);  
        //draw hours rect  
        fill(map(secs, 0, 60, 0, 366), 366, 366);  
        rect(0, height/2, width, height/4);  
        //draw days rect  
        fill(map(mins, 0, 60, 0, 366), 366, 366);  
        rect(0, (height/4)*3, width, height/4);  
    } else {  
        // 2,3, 6 , 7 ,10,11,14,15,18,19...  
        fill(map(mins, 0, 60, 0, 366), 366, 366);  
        rect(0, 0, width, height/4);  
        fill(map(secs, 0, 60, 0, 366), 366, 366);  
        rect(0, height/4, width, height/4);  
        //draw hours rect  
        fill(map(mins, 0, 60, 0, 366), 366, 366);
```

```
    rect(0, height/2, width, height/4);  
    //draw days rect  
    fill(map(secs, 0, 60, 0, 366), 366, 366);  
    rect(0, (height/4)*3, width, height/4);  
  }  
}
```

```
void drawWaveRects() {  
    //draw secs rect  
    fill(map(secs, 0, 60, 0, 366), 366, 366);  
    rect(0, 0, width, height);  
}
```

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